

## Gaia and the Mediterranean Sea\*

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**SUMMARY:** The Earth is a self-organizing system like a living organism. Lovelock proposed Gaia as a metaphor to designate the check and balance of terrestrial temperatures: the Earth is never too hot so that the ocean could boil, and the Earth is never too cold that the ocean could freeze from top to bottom. Hsü proposed that Gaia is endothermic because the life on Earth has been alternate successions of air-conditioners and heaters which evolved and deactivate or reinforce the terrestrial greenhouse of carbon dioxide in atmosphere. When Earth was heating up too much, the air-conditioners, such as anaerobic bacteria, cyanobacteria, skeletal organisms and trees, and finally calcareous plankton, went to work to bring the terrestrial temperature down. When the Earth was freezing at times of continental glaciation, heaters went to work, such as methanogenic bacteria, Ediacaran faunas, tundra and desert plants, and now *Homo sapiens*. Gaia has to have other organs to keep the self-organizing system vital. This paper presents a postulate that the Miocene Mediterranean Sea acted as Gaia's kidney. The steady influx of dissolved ions and debris into the ocean causes inevitable increase of ocean's salinity. The fossil and geochemical records indicate that the ocean has never been too saline nor too brackish for the survival of normal marine organisms: the salinity ranged from about 32 to 36 pro mil during the last billion years. Ocean-drilling cruises to the Mediterranean discovered a very large salt formation, deposited during some 5 million years ago when the Mediterranean dried up. A study of the geochemical balance of the oceans indicates that the deposition of very large salt bodies in isolated basins such as the Miocene Mediterranean every 100 million years or so. The saline giants have the function of Gaia's kidney. With periodical removals of the salt ions and the heavy metals from seawater, the world's ocean have been rendered forever habitable. Gaia has to have a kidney. The desiccation of the Mediterranean is the evidence of a functioning kidney. Earlier "kidney functions" were performed during the deposition of the Cretaceous (South Atlantic), Jurassic (Gulf of Mexico), Permo-Triassic (Europe), Devonian (Canada), Cambrian/Precambrian (Gondwana) saline giants.

*Key words:* Gaia, self-organizing, terrestrial greenhouse, evolution, Mediterranean, saline giants, Gaia's kidney.

### GAIA AS A SELF-ORGANIZING SYSTEM

Venus is dead: with surface temperature more than 600°C; the planet is an inferno of fire. Mars is dead: with surface temperature more than 100°C below freezing; there is no water to sustain life. Our planet is alive and populated with living organisms. Earth has always been alive, during the last 3.5 billion years at least: with the ocean that has never boiled nor completely frozen to the bottom, life on Earth has never been completely extinguished.

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The surface temperature on planets depends upon (1) solar radiation received, (2) solar radiation lost through reflection from planetary surface - the albedo effect, (3) reflected solar radiation trapped by greenhouse gases (carbon dioxide and methane) in atmosphere, - the greenhouse effect.

Solar input was weaker in the beginning of the Solar System, the greenhouse effect of early terrestrial atmosphere had to be some 600 times greater than that of the present in order to keep the global temperatures within the present range. However, the solar radiation increased rapidly and reached the present level some three billion years ago, and the

level has remained more or less constant since. Solar variations, small as they are, may have an influence on the terrestrial climate of the last 2 billion years, but we have also to consider the albedo and the greenhouse effects.

James Lovelock was the first to propose the Gaia hypothesis. He used the metaphor and a parable of white and black daisies to illustrate his idea that the albedo effect has influenced climate. At the time when white daisies took over the world, the albedo effect would become very large and global temperatures are reduced. The ecological impact of global chill, Lovelock speculated, is to reduce the population of the white daisies and to broaden the distribution of black daisies on Earth. The black dominance should then reduce albedo, causing global warming and a return of the white daisies. His hypothesis of alternate dominance of a pair of mythical plants illustrated the concept of a strange attractor: the rise and fall of different species of living organisms have provided a feedback mechanism to make the Earth a self-organizing system. White daisies exist today, but they have never been a dominant species on the surface of the Earth, whereas black daisies never existed. In fact the history of Earth's albedo is largely unknown. Lovelock's idea of Gaia is nevertheless attractive, if we forget about his white and black daisies. The essence is to consider the Earth a self-organizing system.

Gaia's strange attractors in a real world are not the albedo but the greenhouse effects. I presented a modification of the Gaia theory in a talk at the British Association of Advancement of Science, and speculated on a correlation of planetary temperatures to the evolution of organisms which played a significant role in the carbon-cycling of the earth (Hsü, 1992)

Carbon dioxide on Venus has been released from the planetary interior at a faster rate than that escaped from the Venusian stratosphere. Accumulating the surplus over billions of years, Venus is enveloped in a dense atmosphere of carbon dioxide, and the planet has become an inferno of fire. Carbon-dioxide has also been released from the interior of Mars, but the rate has been less than the escape rate. The ever-decreasing greenhouse effect could not maintain a habitable surface temperature, and the situation became worse when the lowered temperature caused the last remaining carbon dioxide to be frozen into dry ice.

The concentration of the greenhouse gases in the terrestrial atmosphere has varied, but the variation

has been moderated because there is life on Earth. A living organism makes sugar out of carbon dioxide and water. After the organism dies, its dead body is changed back into carbon dioxide and water. As it is said by Jesus: Render to Caesar the things that are Caesar's, and to God the things that are God's (Matthew 22:21). In a perfect carbon-recycling process, as much carbon dioxide is returned as it has been utilised by living organisms. At the same time, the planet's atmosphere should get increasingly enriched by the volcanic carbon dioxide. A perfect recycling by living organisms would thus have given rise to an increasingly denser atmosphere of carbon dioxide. Fortunately, the recycling has not been perfect: a small fraction of life's dead remains have been fossilised. In coastal swamps, for example, plant remains are carbonised. On tidal flats, cyanobacteria precipitate carbon as calcium carbonate. The carbon-fixation reactions are common sedimentary processes on Earth: dead plants make coal, and cyanobacteria make limestone.

There has never been too much, nor too little carbon dioxide in the terrestrial atmosphere. The carbon-cycling on Earth can be compared to money-circulation in market-economy. More money in circulation causes an inflation. And fear of inflation makes the Federal Reserve Board to increase of interest-rate. The rate hike discourages borrowing and serves to reduce the money circulation, effecting a deflation. Deflation can lead to recession or even to a great depression. The Federal Reserve has to intervene again, and lower the interest rate at the proper moment inflates the economy. Paraphrasing the economic phrases with scientific jargon, we might state that more carbon dioxide in the atmosphere causes a rise of planetary temperature. Before the Earth's climate got too hot, carbon-fixing organisms evolved and became dominant. They were the "air-conditioners;" they could remove atmospheric carbon dioxide to decrease the global temperature. Global chill can, and did take place several times in the Earth history, and there were ice ages. Gaia has, however, always had newly evolved organisms, which could render a net increase of greenhouse gases in the atmosphere: they were the "heaters." The biologic evolution on earth has been an alternate dominance of the "air-conditioners" and the "heaters," to moderate the climate changes on Earth.

Venus is dead, even if there ever was life. The organisms that might have once existed were not sufficiently efficient "air-conditioners" to take out enough carbon dioxide from the planetary carbon-

cycling. Venus was to get steadily hotter till the planet became uninhabitable. Mars is dead, even though there may have been life. The living organisms were not sufficiently efficient “heaters” to maintain enough carbon dioxide in Martian atmosphere. With a steady loss, the Martian greenhouse became insufficient to prevent the freezing of the planet. Mars died perhaps some 3 billion years ago, when the solar energy radiated by Sun was only a fraction of what it is now. Without an effective protection by greenhouse gases, no life could exist on Mars. The Earth has the blessing of Gaia: Earth has escaped the fate of Venus or of Mars.

How did Gaia manage?

### GAIA'S STRANGE ATTRACTORS

Climate is an essential environmental factor in our survival. Life prevailed on Earth indicates because the ocean has never boiled nor has it ever been completely frozen to bottom. Gaia has given us a “terrestrial thermostat”, and her regulators are the living organisms. The carbon-cycling by the various forms of living organisms has played the critical role in determining whether the Earth was glaciated or ice-free.

Continental glaciers left their signatures in the moraines. Moraines indicative of the last Ice Age are found in Scandinavia, in central Europe, and in North America. Moraines indicative of ancient glaciations are present in older rock formations. The last Ice Age ended only 15,000 years ago. There was an older ice age 350 to 300 million and another 650-600 million years ago.

An ice age is not a period of continuously cold climate. The most recent Ice Age lasted for about 2 million years, but it was not always chilly. Giant ice caps covered Europe, and North America during the glacial stages only. The climate was as warm or even warmer than that of the present during the interglacial.

The cause for the alternation of glacial and interglacial stages is now attributed to astronomic factors which govern the flux of solar radiation on earth. There has to be, however, an ultimate cause for ice ages, because the earth's climate has to be cooled down to such an extent before astronomical factors could trigger alternating glacial and interglacial stages. This ultimate cause for the last Ice Age is the steady reduction of the greenhouse gases in terrestrial atmosphere during the last 100 million years.

The present atmosphere has a small concentration of 0.03% carbon dioxide. Carbon dioxide absorbs solar radiation, like the glass of a greenhouse, and causes thus atmospheric warming. Theoretical computations indicate that a doubling of the atmospheric carbon dioxide would cause a rise of earth's surface-temperature by a few degrees celsius. When the atmosphere is depleted of carbon dioxide, the earth's surface is cooled down. There is geochemical evidence relating atmospheric carbon-dioxide to climate, but why should the concentration of carbon dioxide ever vary?

The variation is a matter of balancing supply and demand. The ultimate source of terrestrial carbon dioxide is volcanic eruption and the sink is carbon sedimentation. The input and deposition cannot always be balanced, and the atmospheric carbon dioxide has been enriched or depleted in response to the evolution of the dominating life forms on earth.

### TIME AND CHANCE

Geochemical studies indicate that the total living biomass on earth has remained more or less the same during the last three and half billion years, but the kinds of the living biomass have been changing in the course of evolution.

In the beginning, some 4 billion years ago, life was sparse or absent on Earth. Volcanism was producing carbon dioxide at such a rate that the primeval world was becoming too hot to be habitable.

Gaia intervened: there had to be life to do the “air-conditioning.”

The primeval atmosphere consisted of nitrogen, carbon dioxide and methane, and there was no oxygen. The only organisms that could have survived under such anoxic condition were anaerobic bacteria. When they died, their dead bodies should have been changed back into carbon dioxide and water. Some parts, however insignificant, were fossilised as organic carbon and buried underground to become graphite. The rate of carbon-burial was slightly greater than the rate of carbon-input from volcanism. The consequence was a systematic depletion of atmospheric carbon dioxide and global cooling.

The “air-conditioning” by anaerobic bacteria was becoming too effective some three billion year ago: there was a threat of fridity. The Earth was on its way to become too cold to be habitable.

Gaia intervened: there had to be “heaters.”

Those were methanogenic bacteria. The bacteria ate up calcium carbonate in anoxic environments to produce methane (CH<sub>4</sub>), a greenhouse gas even more effective than carbon dioxide. The methanogenic bacteria worked hard, and Earth was getting too warm after half a billion years.

Gaia had to intervene for the third time: the world would now again be given to the “air-conditioners.”

Cyanobacteria, also known as blue-green algae, are seen today forming algal mats on tidal flats. Their photosynthetic activities cause the precipitation of lime muds, to be lithified as limestones with layered structures called stromatolites. The ancient cyanobacteria too were doing too good job, and Earth was to be covered by ice on continents some two billion years ago.

Gaia had to intervene once more: there had to be “heaters.”

Photosynthesis produced oxygen. The terrestrial atmosphere became oxygenated two billion years ago, and the condition was ripe for the survival of animals, which breathed oxygen. Worms started to evolve some 1 billion years ago. They burrowed in muds, feeding on cyanobacteria. After they died, their decayed bodies release carbon dioxide to the atmosphere to ameliorate the climate. The climate was ameliorated, but the first “heaters” lost eventually their war, and cyanobacteria continued their dominance to chill the earth. The continental glaciers came again, during several glacial stages 700 to 600 million years ago. The refrigeration was getting so severe when tropical lowlands were being glaciated.

Now Gaia had to produce more “heaters.”

Medusa-like animals made a first appearance 600 million years ago. They were to become increasingly dominant while the worms continued to feed on cyanobacteria. Now the combined efforts of those “heaters” won the war: the Earth came out of an ice age, and the road was open to the “Cambrian Explosion”. The end of glaciation coincided in the timing with the dominance of soft-bodied animals. They are called the Ediacarans, named after the locality in Australia where first such fossils were found.

Then the Ediacarans went too far, and Gaia had to produce more “air-conditioners”, The event is called “Cambrian Explosion” because there was apparently an explosion of evolutionary development.

Is it an explosion or is it only apparent?

Conventional wisdom tells us that life started at the beginning of the Cambrian 550 million years ago because no fossils have been found beneath a geo-

logical formation called Cambrian. It seems that the diverse life appeared suddenly and simultaneously every where. Even more puzzling is the fact that almost all major groups of the animal kingdom are represented by Cambrian fossils. The term “Cambrian Explosion” has been coined to describe an apparently explosive development.

Religious fundamentalists who style themselves as Old-Earth Creationists have seized upon the evidence to support their contention that life was created by God at the beginning of the Cambrian Period. Even a Neo-Darwinist like Stephen Jay Gould assumed an explosive beginning of life, and evolution was portrayed as a process of natural selection by eliminating the unfit; only the favoured races have been preserved because they have been adaptable to changing environments.

Recent discoveries suggest that so-called explosion is not real. The apparent simultaneous appearance of many organisms is an artifact of fossil-preservation. Assuming that all the first animals were skeletal and preserved as fossils, paleontologists postulated that the ancestors of practically all of the living animals were created during the 30 million years of the Cambrian Period. The numerous findings of Precambrian boneless fossils indicate that the evolution of animals started at a far earlier date. Worms left their trails on tidal flats 1000 million years ago. Sponges evolved and their silica spicules were found in rocks 800 million years old. Then came the medusa-like Ediacaran animals, and they were already diversified 600 million years before present. Other fossil faunas with their soft parts preserved have been found in Cambrian formations. The first animals were not created at the beginning of the Cambrian Period; they had evolved during the Precambrian age from ancestors that had no calcareous skeletons (Hsü, 1996).

Toward the end of the Precambrian time, the ubiquitous algal-matt communities were destroyed by the Ediacarans. Calcium carbonate was thus no longer precipitated on tidal flats. The consequence was the release of CO<sub>2</sub> to the atmosphere and the flux of calcium to the ocean. Some of that was taken up by green algae that precipitated calcium carbonate, but enough excess was there to cause an increasing concentration of calcium ions in marine waters. Eventually at the beginning of the Cambrian Period, the open ocean became, for the first time in Earth history, saturated with calcium carbonates. Marine animals could now form calcareous hard parts. The evolution of skeletal organisms

can thus be considered Gaia's counter-measure to curb the Ediacarans' extreme. She had her new "air-conditioners" and the climatic trend was reversed.

Skeletal organisms were not enough, and the Earth was getting still hotter. Gaia needed more "air-conditioners", and they came in the form of land plants. The warm lowlands were forested. Trees grew, taking carbon dioxide from air, and trees died, storing the carbon as coal underground during the Carboniferous Period.

Gaia's "air-conditioners" again overdid it. The atmospheric carbon dioxide was almost depleted through the spread of the forests. The consequence was another continental glaciation some 300 million years ago. Tropical forests could not survive in such glacial chill, and they were replaced by tundra vegetation or by desert plants. The sparse vegetation gave back (after their demise) to the atmosphere what they had taken. The greenhouse gases were further replenished by volcanism. The Earth was heating up again. Polar ice caps were melted, and shelf seas inundated the continents.

The warm climate driven to the extreme was not to produce unhealthy marine habitats. The thermal stratification of the ocean caused periodic stagnations. Some 150 to 100 million years ago, the deficiency of oxygen in ocean water was a hostile environment to ocean life, and there were great dyings of bottom-dwelling animals. Gaia had to intervene again!

Trees, the proven "air-conditioners", were called back, although the newcomers belonged to a new class; they were the ancestors of the flowering plants. Photosynthesis extracted atmospheric carbon dioxide. Calcareous plankton, another kind of "air-conditioners", also evolved, and they withdraw calcium carbonate from seawater to make pelagic limestone. Both effected a depletion of the atmospheric carbon dioxide. There was a steady cooling of the global temperature during the last 100 million years. Eventually, some 40 million years ago, the Antarctic Ice Cap came and expanded. The albedo of Antarctic ice, the heat-transfer by Antarctic Bottom Water (AABW) all contributed to further chilling. The nutrient-transfer by AABW brought phosphorous to the tropics for the blooms of calcareous plankton, causing further reduction of the terrestrial greenhouse gases. The Earth got colder and colder, and an ice age finally came to the Northern Hemisphere 2 million years ago.

## GAIA'S KIDNEY

We usually think of our kidneys in connection with their function of producing urine. Another important function of the kidneys is to maintain the composition of our body fluid, our blood, our "internal environment". The kidneys play a vital role in the precise conservation of salt and water.

The body fluid, the circulating blood of Gaia is the ocean, and ocean consists of salt and water. The salt content of ocean water is its salinity. Ocean water trapped in ocean sediments as old as two hundred million years has been routinely analysed by scientists of the Deep Sea Drilling Project. There is no evidence that the ocean water has changed its salinity significantly in the course of the more recent geologic history. Paleontological criteria have verified this conclusion through studies of the habitats of marine organisms. There are normal marine organisms. There are hypersaline, brackish-water or euryhaline organisms. Those organisms live in normal marine, hypersaline, brackish, or euryhaline environments now and they lived in those respective environments during the geologic past. Some organisms, such as bryozoans are very sensitive indicators of the varying salinity of normal marine environments. Specialists among you marine biologists recognise, for example, that the different species of bryozoans live in seawater of slightly different salinity off the Mediterranean coast.

The ocean water, like carbon dioxide, comes from the Earth's interior. The Earth has an ocean, but the moon does not, because the terrestrial gravitational field is sufficiently great to minimize the escape of water vapour from the atmosphere. The vapour condensates and is precipitated in part as rainfall into the ocean, whereas the rainfall on land also finds its way to the ocean.

The mineral content of the ocean comes from the erosional debris of rocks on continent transported by rivers into the ocean. Sand, silt, clay, and other relatively insoluble detritus are deposited as detrital sediments. Trace elements are absorbed, at least in part, by living organisms or by sediments and thus removed from the ocean water. More soluble major constituents remain dissolved, and they include sodium, magnesium, potassium and calcium cations, and chloride, sulphate and biocarbonate anions. The ocean salinity range from 32 to 36‰, with an average of about 34.5‰.

The average area of ocean is 360 million km<sup>2</sup>, and the mean depth is 3.7 km. The total volume of

the ocean water is thus 1350 million km<sup>3</sup>, weighing 1.4 x 10<sup>18</sup> tons. The total salt content of the oceans is thus about 5 X10<sup>16</sup> tons. The earth is 4.5 billion years of age. The annual influx of salt should have been 10<sup>7</sup> tons per year, if all the soluble salts brought to the ocean stay dissolved in the ocean water.

Another approach to estimate the annual influx of salt is to calculate the annual water-badget. Assuming an average evaporative rate of 1.2 m per year, the annual water loss of ocean due to evaporation should be about 0.4 million km<sup>3</sup>. Of those some 3/4 or 0.3 million km<sup>3</sup> should have fallen directly back to the ocean, and some 1/4 or 0.1 million km<sup>3</sup> represents annual river-discharge. Assuming that the ocean water-volume has not changed, the annual salinity change results from the addition of dissolved material brought in by rivers. The dissolved matter in regions of very wet climate has a very small concentration of 0.1 g/l, i.e., 10<sup>5</sup> tons per km<sup>3</sup> (Clarke, 1924). Using this minimum value as the average for all river-inputs, the annual salt influx to the ocean should have been 10<sup>10</sup> tons. The accumulation of salts in the oceans during the last 4.5 billion years should have been about 5 x 10<sup>19</sup> tons, i.e., a thousand times more than that calculated on the basis of the salt balance of the oceans.

One could assume, of course, the current input has been grossly over-estimated because of the very large land area and the very high erosional rate at the present time. Nevertheless the discrepancy is too great to be overlooked. Furthermore, giant salt formations are present on Earth, and the salt ions must have been removed.

Considering Gaia as a self-organizing system, we could ask if she has a kidney? Has her kidney played a vital role in maintaining the salinity of the seawater? Where is her kidney?

## THE MEDITERRANEAN SEA WAS A DESERT

The Mediterranean Sea 20 years ago was a broad seaway linking the Indian and Atlantic Oceans. With the collision of the African and Asiatic continents and the advent of mountain-building in the Middle East about 15 million years ago, the connection to the Indian Ocean was severed. Meanwhile, the communication to the Atlantic was maintained only by way of two shallow straits: the Betic in southern Spain and the Rhipian in North Africa. The Mediterranean environment gradually deteriorated. The Mediterranean

bottom waters, especially those in the eastern basins, became more and more stagnant, leading inevitably to the extinction of bottom dwellers. The swimming and floating populations struggled for existence. As the salinity of the Mediterranean Sea became abnormal, only euryhaline forms survived.

The Mediterranean Sea has an area of 2.5 million km<sup>2</sup>, an average depth of 1.5 km. The water volume of the Mediterranean Sea is thus 3.7 million km<sup>3</sup>. Lotze (1967) gave the following water balance:

$$E - (P + R) = I - O$$

where E, the annual volume loss by evaporation is 4.69 x 10<sup>3</sup> km<sup>3</sup>

P, the annual precipitation is 1.15 x 10<sup>3</sup> km<sup>3</sup>

R, the annual volume delivered by river inflow is 0.233 km<sup>3</sup>

I, the estimated inflow from the Atlantic is 55.2 x 10<sup>3</sup> km<sup>3</sup>

O, the estimated outflow to the Atlantic is 51.89 x 10<sup>3</sup> km<sup>3</sup>

The net loss of the Mediterranean E - (P + R) amounts to 3310 km<sup>3</sup> annually, and this loss has to be compensated by an inflow from the Atlantic. Geological evidence indicates that the net inflow was considerably less than the net loss, and the Mediterranean sea-level was once drawn down until a complete desiccation (Hsü *et al.*, 1972).

The history of the Miocene Salinity Crisis has been documented by the Upper Miocene sediments on land. Müller and Hsü (1987) suggested the following scenario for the salinity crisis on the basis of their studies in Spain.

The Mediterranean basins were almost completely dry at about 5.7 million years before the present. The isolation was triggered by an expansion of the Antarctic Ice Cap. After a drop of sea level of dozens of meters, the shallow shoal south of the Gibraltar became an isthmus. Canyons were cut by European and African rivers emptied into the Mediterranean basins, with their bottom 2,000 m or more below the global sea-level. The chemical reactions between the desiccated ocean ooze and the groundwaters formed a caliche type of sedimentary rock, called *calcaire di base* in Sicily.

A minor retreat of the Antarctic ice caused a slight rising of the global sea level. The Atlantic water found its way spilling across a series of lakes that extended from Cadiz to Valencia. The seawater flowed through the lakes of descending lake-levels at such a fast rate that the lake water was nearly nor-

mal marine so that coral reefs could grow on lake shores. The Atlantic water cascaded down a grand canyon, which is the now submerged Valencia Trough. Relentless evaporation in seawater in Mediterranean basins caused a conversion of normal saline seawater into brines supersaturated with sodium, potassium and magnesium salts.

The average of the Mediterranean Sea is 1.5 km. The thickness of evaporite deposited by a basin full of water filling up the Mediterranean would be only about 20 m thick, if the salt deposit is evenly distributed. If the salt is restricted to the deepest depressions of the Balearic, Tyrrhenian, Ionic and Levantine basins, the thickness of the salt formation from the desiccation of one basin-full of water should be 100 m or so. Seismic evidence indicates a salt thickness of 1 to 2 km under the abyssal plains of the Mediterranean basins. Obviously, the salt ions have brought in by an influx with a total volume more than 10 times that of the basin, i.e. some 40 million km<sup>3</sup> of seawater have cascaded down the Valencia Trough.

Geologic evidence dates the salt-deposition to an interval between 5.7 and 5.5 million years before present. The rate of seawater-influx should thus have been 200 km<sup>3</sup> per year, a rate larger than that of the Victoria Falls. The influx was not much less than the evaporative loss, because the salt basins were submerged under deep brine-pools when the Lower Evaporite or the Main Salt Body was deposited, the evaporative loss having been one or two orders of magnitude less than the present because of the drastic reduction of the brine-covered area.

The salt deposited in the Mediterranean is ions removed from the global ocean. A volume of 40-million km<sup>3</sup> seawater contains 3 x 10<sup>15</sup> tons of salts.

If the total salt influx to the oceans was 10<sup>10</sup> tons per year, the rivers of the world would have supplied 2 x 10<sup>15</sup> tons to the oceans during the 0.2 million years of the Mediterranean desiccation. The reduction of the salinity of the ocean would have been 2%, i.e., the average ocean salinity would have been changed from 34.5 to 33.8‰. If, however, the total salt influx to the oceans was 10<sup>9</sup> tons or 10<sup>8</sup> per year, the rivers of the world would have supplied 2 x 10<sup>14</sup> or 2 x 10<sup>13</sup> tons to the oceans during those 0.2 million years. The reduction of the ocean-salinity would have been 6%, i.e., the average ocean salinity would have been changed to 32.3‰. There has been considerably amount of salt removed from the ocean, but the salinity-change is still sufficiently small not to be detected by any except the most sensitive marine organisms.

Saline giants such as the Mediterranean Evaporite Formation are rare, but not unique, occurrences in the geological record. Comparable giants are the Mid-Cretaceous of the South Atlantic, the Jurassic of the Gulf of Mexico, the Permo-Triassic of Europe, the Devonian of Canada, the Cambrian/Pre-cambrian of the Gondwanaland. Those six giants during the last 600 million years suggest the need for Gaia to maintain her health through the functioning of her “kidney” every 100 million years.

This frequency of saline-giant deposition places a limit on the average influx rate of salt ions to the oceans. If the total salt influx to the oceans is 10<sup>10</sup> tons per year, some 10<sup>18</sup> tons would have been added to the ocean in 100 million years. The ocean salinity would have been 20 times the normal before a saline giant performed its function as a Gaia’s “kidney.” We have no geological evidence that such drastic catastrophe has ever happened. The annual salt influx to the oceans must have been much less. With an annual 5 x 10<sup>7</sup> tons influx from the continent, the addition would have been 5 x 10<sup>15</sup> tons per year after 100 million years. The increase of the ocean salinity would have been 10%, e.g., from about 32.3‰ to 35.2‰. Such a slow change over a long interval should not have been so devastating to influence the ecology of marine organisms.

In conclusion, the juggling of figures points out:

1) The addition of salt ions to the oceans cannot have been 10<sup>10</sup> tons per year, as estimated by geochemists on the basis of studying the salt flux of Recent rivers.

2) A slow addition of about 5 x 10<sup>7</sup> tons per year contributes to a gradual increase in ocean salinity, but the change was so slow and so gradual that it could not be manifested by the paleontological and geochemical records.

3) The rapid deposition of dozens of kilometres of salts in isolated basins such as the Miocene Mediterranean is a necessary process in a self-organizing system. Without the removal of the salt ions, and heavy metals such as lead, zinc, osmium, uranium, etc. from normal ocean waters, the world’s ocean would have become uninhabitable. Gaia would have died if she did not have a healthy kidney.

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