▪ Introduction ▪

The Science Innovators: an historical context

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Over the centuries, the most innovative scientists have often challenged mainstream thinking by redefining our scientific understanding of nature. They recognise that science is not a static thing. It is moving, alive and always changing.

It has also often been true that authorities unite against the best and brightest scientific thinkers. This opposition to innovative thinking is really a symptom of something deeper. Authorities don't like change. Their greatest fear is the freedom of thought which it represents. If scientists stay true to their own logic it frustrates the grey people of the establishment who see no need for change.

The most innovative thinkers often find themselves labelled as rebels who are too dynamic and individualistic, something to be feared. Although deviation from convention is required to advance scientific understanding this is sometimes discouraged by society and peer pressure. Since the most innovative scientific discoveries often challenge mainstream thinking these pioneers are routinely sidelined, even by other scientists.

The earliest science innovators

Socrates was a classical Greek philosopher credited as one of the founders of scientific method. He is one of the most well-known science innovators. Socrates developed this new scientific method to challenge the superstitious beliefs that had reigned for millennia, although his search for truth would eventually result in his death.

Socrates was born in Athens to a midwife and a stonemason around 469 BCE. He grew up in a society that was undergoing a tremendous transformation. At the time, the Greeks believed that gods, demigods

and spirits were all around influencing people's lives. Most Athenians believed that they could sacrifice offerings to the gods to change their own destiny.

As a teenager Socrates listened to new theories brought in by the traders. He encountered new ideas from the eastern Mediterranean that gave a very different explanation of the formation of the cosmos. A few people were daring to question the religious convention. What the Greeks viewed as mysterious and unknowable they viewed as rational and explainable. All this prompted many young Greeks, including Socrates, to ask hugely ambitious questions like: what is the cosmos made of, what is matter, how do we perceive matter and where has the world come from? Their use of reason was an approach that opened up new ways of looking at the world.

The power of the mind could be used to explain the world around them. All this new thought attracted new thinkers and the city became a magnet for innovation. All this was eagerly taken up by the young Socrates.

Socrates's method was based on debate and he questioned everything. He was an expert in making other people know things by pretending he knew nothing. Because it was in an oral context he could use the pretence of being the fool, an ignorant man. He was able to use this tool to ask other people to explain seemingly simple questions, breaking down problems into little pieces to analyse each one separately, until he finally grouped them back together into a more general concept. Socrates was able to use this technique to make people aware that some of the facts they considered true were not true. In practice they didn't know what they thought they did. The method was to influence scientific thought for millennia to come.

He was the wisest of men because he knew the limits of his own knowledge. But he also exposed the limitations of the ruling elite who claimed to be knowledgeable. The authorities didn't like how Socrates was encouraging the young to think for themselves. Socrates's ideas were tolerated for many years but then, in 431 BCE a new war broke out and Athens was seized. With the population contained within the city walls a disease spread and it is believed that a least one third of the population was wiped out. With the authorities looking for someone to blame it was proposed that it was Socrates who had angered the gods. Socrates became a perfect scapegoat.

Plato was Socrates's most famous student and he described how, in 399 BCE the philosopher Socrates was accused of "refusing to recognise the gods recognised by the state" and of "corrupting the youth". His three Athenian accusers were allowed to present their case and then the philosopher defended himself. After hearing the

arguments of both Socrates and his accusers, the jury found Socrates guilty and he was sentenced to death. He was required to be his own executioner by drinking a cup of hemlock. Plato later described the scene through the narrative voice of the fictional character Phaedo as he accepted the sentence of death.

> "'I understand', he said, 'we can and must pray to the gods that our sojourn on Earth will continue happy beyond the grave. This is my prayer, and may it come to pass.' With these words, he stoically drank the potion, quite readily and cheerfully. Up till this moment most of us were able with some decency to hold back our tears, but when we saw him drinking the poison to the last drop, we could restrain ourselves no longer. In spite of myself, the tears came in floods, so that I covered my face and wept - not for him, but at my own misfortune at losing such a man as my friend."

Throughout the coming millennia many scientific innovators would often find they would also pay a high price for their dedication to scientific discovery.

Galileo Galilei

Perhaps the most well-known scientific innovator was Galileo Galilei. His maltreatment is often portrayed by scientific intellectuals as a simple battle between science and religion but in reality the divisions were much more deeply ingrained and complex. The so-called trial of Galileo consisted of two separate trials punctuated by decades of scientific conflict. The first trial in 1616 examined the concept of the Copernican doctrine and scientific experts were called to give the opinion of the scientific authorities. Their decision was based on what would today be called the scientific content of the doctrine. The experts declared the doctrine to be "foolish and absurd in philosophy". In more modern terms the mainstream scientific insiders of the time declared it to be unscientific - a pseudoscience. Galileo was forbidden by the court to teach the Copernican system as a truth, although he was still allowed to teach it as a hypothesis.

The second trial from 1632 to 1633 was no longer concerned whether the Copernican system was true of not – that had already been decided by the first trial. The question was simply whether Galileo had obeyed the order given to him in the first trial. The opponents of Galileo criticised him for being devious for continuing to teach an absurd concept.

It would seem obvious to everyone that seeming to agree with the authorities by renouncing the Copernican system while still using

every avenue to support it was the logical choice. The alternative of openingly supporting the concept was not a viable proposition. Only a few decades previously Giordano Bruno had been burned at the stake for refusing to recant his own views about the world. We consider these views obvious today. He believed that the stars might be just like our own Sun, perhaps with planets and other people. This was such an outrageous idea to the authorities that his tongue was cut out before he was burnt at the stake.

Galileo narrowly avoided death but was sentenced to house arrest and forbidden to publish anything. Having only just escaped with his life Galileo continued to find ways around the ruling of the court. While under house arrest he produced one of his finest works, *Two New Sciences*[1], outlining the principles of the two sciences now called kinematics and strength of materials. Galileo was careful to add a note in the preface that this work was not meant for publication but merely a record of his research. The book was then smuggled out to be published in Holland to avoid the censor.

The creation of the Earth

The Earth and its origin have intrigued people since ancient times. The philosophers of antiquity attempted to understand and explain natural phenomena based on the knowledge of their time, often involving deities of some kind. These beliefs had become confirmed as fact before the Christian era but with the coming of Christianity the Biblical account of the creation became the dominant force in most of Western Europe. They believed the Earth had been created just as it was now. Many pre-Christian ideas where either ruthlessly stamped out and denounced as pagan, or incorporated into Christian teaching, particularly about ancient change in the landscape and Earth, since much of the evidence was too obvious to be entirely disregarded. The observations many people continued to present seemed to prove the Earth had once suffered massive changes and this allowed many philosophers to believe that nature was now in a complete state of rest. The creation myth became so deeply rooted in all science subjects that it spread its tentacles far and wide to provide a distortion of the true nature of the world. Based on the accepted creation theories of the Earth it seemed that the present surface of the Earth must remain unaltered and would remain unaltered forever.

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[1] *Galilei (1638).*

In the late 17th century James Ussher was the Church of Ireland Archbishop of Armagh and Primate of All Ireland. He was a scholar who was highly skilled in languages, history and astronomy. His medieval mind was dominated by the church and its teachings, so even when he used logical scientific deduction it was applied in the context of the Bible's account, based on the assumption that the Bible was true. Ussher used very precise calculations to find the date of the creation of the Earth. After carefully calculating all the biblical births and lifespans stated in the Bible he predicted that the precise date of creation of the Earth was 22nd October 4004 BCE. The results of such painstaking calculations impressed many and Bibles began to be printed with the exact date of creation contained in the margin to remind the faithful when the world began.

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Georges-Louis Leclerc, Comte de Buffon, a leading French naturalist, mathematician, cosmologist, and encyclopedic author is one scientist who challenged the widely held belief in an Earth that was created in 4004 BCE. His wide interests in the world were recounted in his 36-volume encyclopedia called the *Theory of Nature*, which were published from 1749 to 1785. These publications made him one of the most famous scientists of the time. His books became the popular science bestsellers of the day, feeding a new public interest in the scientific discoveries of the age.

The publication of his new scientific theories soon caused friction with the religious authorities. After the publication of his theory about the natural history of the Earth he received an official letter in January 1751 from The Faculty of Theology in Paris. These authorities informed him that his works were "contrary to the creed of the church" and requested he recant his unorthodox opinions. Once he submitted this he was then required to publish his recantation in his next work. Thus his next book begins with these words:

> "I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and I abandon everything in my book respecting the foundation of the Earth, and, generally, all which may be contrary to the narration of Moses."[1]

Despite the introduction his readers were presented with a scientific method of experiment and logic indicating that the Earth might be very old, certainly a lot older than the 6,000 years allowed by the Bible.

[1] *Leclerc (1751).*

Buffon described how he had thought he might establish the age of the Earth by a novel experiment. In 1741 he had heated a small and large black metal ball to red heat in a blacksmith's forge and then timed how long they took to cool. If it was assumed that the world had begun life as a red hot globe and had then gradually cooled it would be possible to work out how old the Earth really was by simply timing how long it took the different sized balls to cool down. The larger ball retains heat for longer than the smaller one because of the scale effect. A larger sphere double the size of a smaller one would have eight times the mass but only four times the surface area. The larger sphere would therefore retain the heat longer. Then using the difference in rate of cooling between the small and large balls he extrapolated the data to a much larger diameter Earth to calculate that the Earth was 74,832 years old. It was clearly a very different figure than suggested by the Bible.

By the beginning of the 19th century scientific enlightenment began to become more established throughout Europe. It began the belief in liberty, equality, tolerance and the importance of education for all. These views were most profoundly expressed in the French Revolution in 1789 and this concept of freedom of thought continued even after Napoleon announced that he would be crowned Emperor of France. Paris started to attract many of the leading free thinkers of the day. No other city was so deeply steeped in science. After the French Revolution the role of the Catholic Church had diminished so that thinking was allowed to become liberal and free. It attracted many scholars because they were allowed to speculate without prejudice. The whole city was buzzing with new ideas.

The Natural History Museum in Paris was expanded with new collections that had been seized by Napoleon's army. The Jardin des Plantes housed plants that had been brought back from all over the world. The Académie des Sciences was the centre of most scientific enquiry. When Alexander Humboldt returned from his scientific exploration of South America he delivered a series of lectures about his explorations to packed audiences at the Académie des Sciences. The chemist Louis Gay-Lussac was enthralling the whole of Paris with daring balloon ascents above the city.

There seemed to be new and exciting theories everywhere. At the Natural History Museum the naturalist Georges Cuvier and Jean-Baptiste Lamarck introduced new and startling ideas about life itself. Cuvier turned the controversial subject of extinctions into an accepted scientific fact by examining fossil bones and concluding they didn't belong to existing animals. Lamarck developed a theory of gradual transmutation of species, paving the way for evolutionary ideas to

gradually take hold half a century later. The scientists in Paris pushed the boundaries of scientific thought to its very limits.

No vestige of a beginning

James Hutton's geological theory has become so famous that he is often credited as "the father of modern geology". However, that epithet was given to him long after his death and the science authorities of his day weren't convinced he had anything new or worthwhile to say about the Earth.

James Hutton was born in Edinburgh in June 1726. He was interested in chemistry in his youth and chose to study medicine at Edinburgh University since this seemed to be the closest subject to his interest. He subsequently studied at the Sorbonne in Paris, and then Leiden University in Holland, to obtain a doctorate for a thesis on blood circulation.

Hutton never took up medicine. After a brief time as a farmer his interest in chemistry allowed him to become a successful partner in a small industrial factory involving the manufacture of sal ammoniac. This enterprise was so successful that he abandoned farming completely and returned to Edinburgh in 1768 as a gentleman of leisure who devoted himself to scholarly pursuits. After joining the Oyster Club he became close friends with men like Joseph Black the chemist, John Playfair the mathematician, John Clerk the naval tactician, Adam Smith the economist, Robert Adam the architect and the philosophers Adam Ferguson and Dugald Stewart.

It seems that Hutton had become interested in geology during his time as a farmer. He was particularly intrigued by the ditches that had to be dug out each year to remove the soil that had washed into them. He saw an interesting problem in this yearly chore. Where did the soil come from each year? Could it be that the mountains were being eroded down to provide this soil? However, if the mountains were being slowly eroded then shouldn't all land eventually become flat? It was an interesting problem that Hutton decided to solve.

It seems that by the mid-1760s Hutton had developed most of his basic theory about geology but had little thoughts about telling anyone about it outside his close circle of friends. The historian Tony Hallam, a Lapworth Professor of Geology, tells us he "evidently had to be prodded by his friends into making his work public".[1] Hutton eventually read a paper about his Theory of the Earth to the Royal Society of Edinburgh in 1785. Three years later it was published in the

[1] *Hallam (1983).*

Society's Transactions with the title: *Theory of the Earth; or an investigation of the laws observable in the composition, dissolution, and restoration of land upon the globe*[1].

Hutton's concept was amazingly original in that he had solved the problem of erosion of the mountains. He proposed that sediment was laid down in the sea to form new land, then the buildup of heat in the Earth's interior had caused volcanoes to uplift the land to form new mountains, until these new mountains were in turn worn down by erosion. It was a continuous cycle of erosion, sedimentation and uplift that must have existed for an immensely long time and would continue to exist for an unknowably long time in the future. His theory explained why there were marine fossils on land and why volcanoes must exist. Our Earth wouldn't have formed without them.

Hutton concluded his 1788 paper with his most famous sentence:

> "The results, therefore, of our present enquiry is, that we find no vestige of a beginning - no prospect of an end."[2]

Today we know that this was a major revolution in geology but at the time it seems to have been largely ignored, except for attacks by men like DeLuc and Kirwan who seemed mainly upset that Hutton's theory of an immensely old Earth challenged the Biblical account of a young Earth.

Seven years after delivering his talk, Hutton tried to clarify his theory further by writing a three part book, *Theory of the Earth*[3], with the first part published in 1795.

Hutton first describes his views on the problems facing any new theory.

> "A theory which is founded on a new principle, a theory which has to make its way in the public mind by overturning the opinions commonly received by philosophising men, and one which has nothing to recommend it but the truth of its principles... must meet with the strongest of opposition from the prejudices of the learned, and from the superstition of those who judge not for themselves in forming their notions, but look up to men of science for their authority...
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> In order, then, to obtain the approbation of the public, it may not be enough to give a theory that should be true, or altogether unexceptionable; it may be necessary to defend every point that should be thought exceptionable by other theorists, and to shew the

[1] *Hutton (1788).*

[2] *Hutton (1788).*

[3] *Hutton (1795).*

> fallacy of every learned objection that may be made against it. It is thus, in general, that truth and error are forced to struggle together, in the progress of science; and it is only in proportion as science removes erroneous conceptions, which are necessarily in the constitution of human knowledge, that truth will find itself established in natural philosophy."[1]

Hutton's book seems to have been largely ignored by most scientists of the day, just like his original talk and paper. Most found his writing too difficult to read.

Hutton died two years after the first two volumes of his great work came out. He was working on the third volume of his book shortly before he died but this wasn't published at the time. No one was interested apart from friends like John Playfair who was later to write his own book about Hutton's theory of the Earth. Over a century later, the Huttonian geological theory had become so famous that it was finally published by the Geological Society of London in 1899, after the manuscript of the third volume was rediscovered. Today he is often credited as "the father of modern geology" but that is largely because of the efforts of his friends to promote the theory.

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When his friend James Hutton died in 1797 two powerful reasons induced John Playfair, who was then teaching mathematics in Edinburgh University, to present his friend's theory in a different form from the original. Firstly, he felt the detailed style adopted by Hutton rendered his theory less intelligible and much less known than it deserved. Secondly, this lack of lucidity gave rise to misrepresentation and attacks, so it seemed likely that Hutton's theory was only going to be known through the erroneous statements of its opponents if he did nothing. Playfair determined to afford a clear exposition of the theory to repel those attacks. In the end Playfair spent five years, from 1797 to 1802, writing his book about Hutton's theory of the Earth. When Playfair's book, *Illustrations of the Huttonian Theory of the Earth*, was published in 1802 it soon became so popular it helped to widely publicise Hutton's new geological theory to a wider audience.

The *Illustrations* was a model of purity of diction, simplicity of style and clearness of explanation. Playfair's very distinct difference in writing style compared with Hutton's own can be clearly seen in the account of angular unconformities. This is considered to be one of the strongest lines of evidence but Hutton didn't discuss it until chapter

[1] *Hutton (1795).*

six of his book. Playfair highlighted it in such a dramatic style that no one could fail to note its significance.

> "On us who saw these phenomena for the first time, the impression made will not easily be forgotten. The palpable evidence presented to us, of one of the most extraordinary and important facts in the natural history of the Earth, gave a reality and substance to those theoretical speculations, which, however probable, had never till now been directly authenticated by the testimony of the senses. We often said to ourselves, what clearer evidence could be had of the different formation of these rocks, and of the long interval which separated their formation, had we actually seen them emerging from the bottom of the deep? We felt ourselves necessarily carried back to the time when the schist on which we stood was yet at the bottom of the sea, and when the sandstone before us was only beginning to be deposited, in the shape of sand or mud, from the waters of a super-incumbent ocean. An epoch still more remote presented itself, when even the most ancient of these rocks, instead of standing upright in vertical beds, lay in horizontal planes at the bottom of the sea, and was not yet disturbed by that immeasurable force which has burst asunder the solid pavement of the globe. Revolutions still more remote appeared in the distance of this extraordinary perspective. The mind seemed to grow giddy by looking so far into the abyss of time; and while we listened with earnestness and admiration to the philosopher who was unfolding to us the order and series of these wonderful events, we became sensible of how much further reason may sometimes go than imagination may venture to follow."[1]

In 1805 Playfair exchanged the chair of mathematics in Edinburgh University for another in natural philosophy so he was able to continue to publicise his friend's new theory of the Earth.

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Charles Lyell was one 19th century geologist who saw the many advantages of Hutton's radical concept and developed the geological principle that later became known as uniformitarianism. His work influenced the thinking of generations of geologists.

Lyell first took up law as a profession but his passion was geology. Eventually he turned to geology full-time and by 1827 he had embarked on a geological career. He began by working out the implications of the ideas proposed by James Hutton a few decades earlier.

[1] *Playfair (1802).*

Lyell's careful research and thoughtful deductions soon began to have a persuasive influence on many of the scientists of the day. In 1830 he published the first part of his three volume book, *Principles of Geology: being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation.*[1] It was the main geological text book which the young Charles Darwin took on his trip on the Beagle. The scientific topics discussed in his books included a novel explanation of earthquakes and the theory of a gradual building of volcanoes. In stratigraphy he coined names for the geological eras: Palaeozoic, Mesozoic and Cenozoic.

Lyell was one of the first geologists to provide further evidence that the world was immensely older than previously thought. As part of his research Lyell examined the great volcano of Etna on Sicily first hand and studied its history. He noticed how successive eruptions would add new material on top of the previous one to allow the volcano to grow at a measurable rate. Using this data he estimated the age of the volcano was several hundred thousand years old. This age was considered immensely old during the 1800s but it also raised the further question of the age of the volcano in relation to the Earth itself. Had the volcano existed ever since the Earth began or was it only relatively new?

At the very edge of the volcano underneath the first lava flows Lyell found fossil shells that were virtually identical to the shells of molluscs swimming in the Mediterranean. Since the fossil shells were geologically recent he concluded that a hundred thousand years was a relatively short geological time. The only conclusion he could draw was that the Earth was immensely old.

An exact age of the Earth

Arthur Holmes would eventually define a more exact age for the Earth in the early 20th century. He was born in 1890 near Gateshead, a town set in the industrial heartland of north England and lived with his parents in a modest terraced house. His interest in science began to be nurtured at the local Gateshead Higher Grade School.[2]

Holmes appears to have been a naturally logical child. One event that he later recalled from his childhood focused around his parents' Bible. On the margin of the first page was the date of Creation, 4004 BCE, the date calculated by James Ussher in the late 17th century. Even as a child he was puzzled by numerous questions: why was there

[1] *Lyell (1830).*

[2] *See Lewis (2000) for a comprehensive description of Arthur Holmes life.*

an odd 4 instead of a nice round number, why was the date so recent and perhaps most importantly, how could anyone know an exact date? At Sunday School his questions remained unanswered and were even refuted by the Biblical teachings of Philip Gosse who believed that the Earth was created about 6,000 years ago "exactly as it would have appeared at that moment of its history, if all the preceding eras of its history had been real". All nature was reduced to a meaningless illusion. Fortunately the young Holmes could see the fallacy of these beliefs.

As Holmes studied in 1906 he was inspired by the scientific debate in *The Times* about the age of the Earth between Kelvin and some of the big names in science at the time like Ramsay, Rutherford, Soddy and Strutt. It seemed he was watching history unfold as new scientific thinking uncovered the Earth's age. He was captivated enough to start to dream that perhaps he could try to help determine the Earth's age as well, so when he won a scholarship to the Royal College of Science in London he chose physics as his core subject.

The National Scholarship Holmes had been awarded was worth sixty pounds a year. It was hardly a large amount but was just enough to live on while he studied. During the second year Holmes was able to take geology as an optional subject and he was fortunate to have Professor William Watts teaching geology as an exciting and dynamic subject. It was due to Watts's inspirational lectures that Holmes began to seriously think about becoming a geologist. Not only did he find the subject fascinating, it seemed that there were many job opportunities in the mining and petroleum industries for young geologists. Eventually he swapped his core subjects to become a geologist instead of a physicist.

As luck would have it, Holmes never made the full transition to geologist because Professor Robert Strutt joined the physics department. This was the same Strutt who had joined in the debate in *The Times* with Lord Kelvin. Holmes could hardly believe his good fortune and he was soon engaged in trying to determine the age of the Earth through radioactivity. Radioactivity was the geological clock geologists had been looking for to allow them to tell geological time since radioactive elements decay into different elements as regularly as a ticking clock. In their fourth and final year students were expected to contribute original research work so Strutt invited Holmes to help him with his research on radioactivity to determine the age of the Earth. This initial research project would eventually become a lifelong task for Holmes.

In 1908 Holmes started the delicate task of determining the age of the Earth using the uranium-lead technique. In theory it is a simple

procedure but he was still refining the procedure in 1910. When an igneous rock cools from its molten state, different types of minerals will form depending on the elements already present. When a mineral contains radioactive elements such as uranium and thorium those radioactive elements will start to decompose into their daughter elements. Uranium will decompose into lead and thorium also has a decay chain that eventually decomposes into lead. In practice the procedure is far from easy and Holmes spent many tedious hours in the laboratory painstakingly separating crunched rocks, using delicate chemical preparations to isolate the elements for ultimate measurement. Finally, after years of hard work Holmes had determined the very first true age for the Devonian geological age, a truly staggering 370 million years. He had performed the first uranium-lead dating of a rock whilst still an undergraduate.

Holmes's time as a student in London was a constant struggle against financial hardship. Although he was able to earn some extra money reviewing books for *The Times* he was constantly on the lookout to fund himself and his studies. Virtually as soon as his researches were finally compiled in 1911 he joined a company exploring the geological resources in Mozambique. The experience didn't last long for he nearly died from malaria. When he was brought unconscious to the hospital in Mozambique the nuns who ran it had little hope for his survival and a report of his imminent death was telegraphed to London. But, much to everyone's surprise, he didn't die and slowly began to recover. Even today malaria kills around half a million people a year so in 1911 Holmes was very lucky to survive. By the time he returned home after only 9 months away he had amassed enough money to keep himself comfortable for a while and had exciting tales of encounters in deepest Africa and his near death. Nonetheless, the experience left him with recurring bouts of fever that continued to plague him for the rest of his life.

Holmes was now ready to begin his dream of developing a geological time scale. When he returned home he found that his results were not widely welcomed by many older geologists who had come to accept a younger age of the Earth. One of the foremost American geologists of the day, George Becker, had recently published his *Age of the Earth*[1], concluding that the age "must be between 70 and 55 million years" using older methods. He therefore concluded that "radioactive minerals cannot have the great ages which have been attributed to them". In a similar vein the Irish geologist John Joly declared it "seems quite impossible to find any explanation of [the amount of salt in the oceans if such an age was true]". He argued that

[1] *Becker, G. (1910).*

geologists knew "nothing as to the origin of the primary radioactive elements … the rate of change 150 million years ago may have been many times what it is now."[1]

Holmes knew that the arguments against the new dating method were incorrect and was determined to help to explain the new dating technique to his fellow geologists. In 1913 he published a booklet entitled, *The Age of the Earth*[2], which many geologists used to gain an understanding of these new radioactive dating technologies. His booklet explained how it was found that various radioactive elements could be used for different ages. Uranium and thorium decay through several stages into different isotopes of lead at rates that were unaffected niether by temperature or pressure, nor by physical or chemical states. "Half-life" is when half of the radioactivity has disappeared and some could measure many millions of years. Uranium 238 for example has a half-life of 4,510 million years and this isotope yields the ages of the oldest rocks on Earth. Other radioactive elements are common impurities in various forms of rocks. At the same time, the geologist John Joly worked in collaboration with Sir Ernest Rutherford to confirm the estimate that the beginning of the Devonian period could not be less than 400 million years ago. Slowly geologists began to agree they had a fantastic new method to date the Earth.

From Continental Drift to Plate Tectonics

The concept of continental plates fitting together in the past seems so clear today it might be difficult to envisage a time when it wasn't obvious. But history relates a different story. In practice the most obvious concept was that the continents had always existed in their present position. They certainly couldn't move thousands of kilometres to join together and the science authorities derided anyone who suggested they could.

The man most connected to this theory of continents moving over time is Alfred Lothar Wegener, who was born in Berlin in 1880. He first trained in astronomy to gain a doctorate in this subject, but then shifted his main interest to meteorology. Today his most well-known contribution to science is in geology, a subject in which he had no formal training. He developed his concept of continental dispersion over two decades and this came to be more widely known as Continental Drift in the English-speaking world.

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[1] *See Lewis, (2000), p 65.*

[2] *Holmes (1913).*

The main concept of Continental Drift is that the continents we know today have moved position over time. This dispersion has been so great that in the remote past all the continents had been joined together as one great continental land mass before splitting apart. The concept of Continental Drift predicted that about 150 million years ago it would have been possible to walk directly from Europe to America, from South America to Africa, from Africa to Antarctica, and from Antarctica to Australia since they were all joined together in one gigantic supercontinent.

Wegener tells us that the concept of Continental Drift first came to him in the year 1910. While considering a map of the world he noted that the continents of South America and Africa could be fitted together. At first he considered the idea that the continents were once joined together to be improbable. Then, after learning of the similarity of prehistoric animals and plants, he examined the research in the fields of geology and prehistoric life and the evidence he found convinced him that the continents had once been joined in one gigantic landmass. The spark which gave Wegener his new theory was the realisation that the outlines of the continents fit together like an oversize jigsaw puzzle.

It would seem that his father-in-law thought the theory was so outrageous that he tried to dissuade Wegener from persisting with the idea. He preferred his son-in-law to stay focused on the subject he was trained in, meteorology, instead of speculating on subjects in which he was unqualified. Wegener's written reply of January 1911, originally in German but later translated by Anthony Hallam in his 1983 book *Great Geological Controversies*[1], makes it clear that Wegener's logical mind thought the problem so clear and straightforward that the "old ideas" would soon be replaced:

> "I believe that you consider my primordial continent to be a figment of my imagination, but it is only a question of interpretation of observations. I came to the idea on the grounds of the matching coast-lines but the proof must come from geological observations. These compel us to infer, for example, a land connection between South America and Africa. This can be explained in two ways: the sinking of a connecting continent or separation. Previously, people have considered only the former and have ignored the latter possibility. But the modern teaching of isostasy, and more generally our current geophysical ideas oppose the sinking of a continent because it is lighter than the material on which it rests. Thus we are forced to consider the alternative interpretation. And if we now find many surprising simplifications and can begin at last to make real

[1] *Hallam (1983).*

> sense of an entire mass of geological data, why should we delay in throwing the old concept overboard. Is this revolutionary? I don't believe that the old ideas have more than a decade to live. At present the notion of isostasy is not yet thoroughly worked out; when it is, the contradictions involved in the old ideas will be fully exposed."[1]

By the beginning of 1912 he had delivered an address on the idea and had published two papers on the origin of the continents in scientific journals. He continued to amass more evidence that the continents had once been joined in one gigantic land mass 300 million years ago to form a super-continent, which he called Pangaea, which finally broke up into the smaller continents of today. Wegener was immediately called up when the First World War began in 1914 but he was wounded twice on the front in Belgium before being declared unfit for active service. In 1915 he was able to publish a German only book about Continental Dispersion, *Die Entsehung der Kontinente und Ozeane* (The Origin of the Continents and Oceans)[2]. Wegener's book went through further editions in 1920 and 1922 with each edition being thoroughly revised.

Translations of the third edition of his book appeared in English in 1924 and in French in 1927. It soon began to cause a stir in the international geological community. Wegener described his theory as continental dispersion but the German term of dispersion was translated as drift and that became the name it was known by in the English-speaking world. Special meetings began to be called by geological societies in various parts of the world to discuss Continental Drift Theory.

One of the most well-known meetings was held by the American Association of Petroleum Geologists in New York City, hosted by Van der Gracht, in 1928. The meeting was a chaotic mixture of views. The exciting coincidences and patterns in Continental Drift inspired the imagination of some. Sober critics rebelled against a facile selection of facts to fit the theory. While some were advocates most tended towards a conservative view that the theory was something that staggered the imagination and must be rejected for that reason alone. It can't have helped that the theory was now called "drift" in English, seemingly implying an unscientific mechanism for the movement of the continents. The opponents of Continental Drift claimed a comprehensive victory for their rejection of the theory. Wegener remained undaunted by the strong opposition to his ideas. With

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[1] *See Hallam's 1983 translation from German.*

[2] *Wegener (1915).*

feedback from across the world Wegener carefully began revising his book in another edition to answer the critics.

Wegener had made many expeditions investigating the drift of continents. To obtain new evidence for the drift of Greenland, Wegener planned a tough and dangerous expedition there for 1930. The main expedition discovered many new facts, but in November 1930, the harsh conditions of the Greenland ice cap claimed the life of Alfred Wegener.

Wegener's death was just at the decisive moment when he was about to renew the debate. The 1922 edition of Wegener's book had been translated into English, French, Spanish, Swedish and Russian and had begun a world-wide debate. By the fourth edition of 1929 Wegener was able to quote evidence from other workers in the field. Unfortunately this edition was not translated into English and other languages until more than three decades later when the value of Wegener's work was just starting to become more widely recognised. After his death his revised book remained unpublished in English and the sound of battle died away. Many geologists also soon found that it wasn't the best time to support radical new theories. A great economic depression had descended on the world, particularly in Germany but also in other parts of Europe and America, and many people found their job depended on pleasing their superiors. This was particularly true in America were many geologists noted that the only place the theory of Continental Drift was discussed was on the "back stairs" well out of public sight.

A mechanism for Continental Drift

By the late 1920s Arthur Holmes had become a rising star in the world of geology due to his work on the age of the Earth. Then he created controversy by outlining a mechanism for Continental Drift, proposing that differential heating of the Earth's interior generated by the decay of uranium and other radioactive elements would cause convection currents to be set up in the Earth's mantle. If the continents floated on top of the Earth's denser mantle, like icebergs in a denser sea as Wegener suggested, then the continents would be carried by the mantle's convection currents and naturally move apart over millions of years. After he had formulated his ideas he presented a paper in December 1927 to the Edinburgh Geological Society outlining the concept in detail and it was published in 1931.[1] At the time Holmes found many leading geologists, particularly the

[1] *Holmes (1931).*

Americans, ridiculed his ideas as absurd. The leading American geologist William Bowie dismissed his concept with the comment, "Holmes brings out a new thought which is even more impossible than Wegener's."[1]

During the 1930s Holmes's thoughts about the age of the Earth led to requests for him to lecture around the world. He visited Switzerland, Finland and the United States. He also found time to publish numerous papers and served on several committees. Despite all this he was still unable to convince his conservative colleagues of the reality of Continental Drift.

Holmes was looking for a new job when a Professor of Geology position at Edinburgh University became available in October 1942. Edinburgh was one of the top universities in Britain ranking alongside Cambridge University and Imperial College. It was the university where Playfair had hatched the Huttonian egg with his publications about Hutton's geological ideas. Better still, the university's principle, Sir Thomas Holland was a geologist and a supporter of "continental displacement".

Holmes's first lecture was attended by three hundred city dignitaries and prominent members of the university. With a title of *"The Age of the Earth"* Holmes was quick to pay homage to the Scottish geologist James Hutton. It was, after all, Hutton who had anticipated the Earth's great age so it seemed fitting that Holmes could now observe that new science now confirmed those same rocks were immensely old.

By this time most of the world was engaged in the Second World War. Holmes was too old to be called up to fight but he volunteered as a fire-fighter in the university. Staff took it in turns to sit and "fire-watch" in case the building was bombed or set alight. This enforced period of idleness wasn't wasted when it dawned on him that he could use the peace and quiet of the fire-watching duty to write a comprehensive text book about geology. He turned his lecture notes into one of the most celebrated books on geology ever written. Holmes had continued to provide evidence in support of Continental Drift but it was still a very contentious issue in geology at that time so he thought long and hard about whether to include it in his book. His own theory about convection currents in the mantle driving the contents around had been mostly ignored. Raising the question again in his book would leave him open to ridicule. In the end Holmes decided that, since he had been teaching his students about Continental Drift for nearly twenty years, he couldn't leave it out. He resolved to face the inevitable hostility and included all his most recent ideas on Continental Drift in the last chapter of the book.

[1] *See Lewis (2000), p 158.*

The first edition of his book, *Principles of Physical Geology*[1], was published in 1944 and soon became an international best seller. The long winded title was soon dropped by most young geologists who simply called it "Holmes". The first print run sold out almost immediately and it was reprinted no fewer than eighteen times in the next twenty years. Holmes's book inspired many people to become geologists with the big and exciting questions it posed: How did mountains form? What caused earthquakes? And perhaps most radically: Did continents really wander around the globe?

Continental Drift in the Southern Hemisphere

On the opposite side of the world to Holmes was another convert to continental dispersion. Samuel Warren Carey was born near Campbelltown, New South Wales, in 1911. He obtained a College Scholarship and enrolled in Geology as a fourth subject on the advice of one of his teachers. This determined the direction of his career for the rest of his life. He came under the influence of Professor Sir T.W. Edgeworth-David and was introduced for the first time to the concept of Continental Drift as a mechanism capable of explaining important aspects of Southern Hemisphere geology. He graduated with First Class Honours in 1932 and completed a Masters degree in 1934.

During the Second World War Carey was a commando in Z Force and as the war effort began to wind down he took the opportunity to go to Tasmania as a Government Geologist. In 1946 Carey was appointed as the foundation professor in the newly-founded Geology department at the University of Tasmania. Carey had believed from the 1930s that the continents were once connected and so it was only natural that he taught his students what later became known as Plate Tectonics, including the swallowing of the ocean floor at the trenches and the strip-by-strip addition of new ocean floor from the mantle at the mid-ocean ridges.

Many of his contempories saw him as a "larger than life" figure for his vision and the originality of his views. He had a major influence on global science with his enthusiastic support for, what was at the time, the unorthodox concept of Continental Drift. His students saw him as an extrovert who challenged them to question any view that was seen as orthodox simply because the exponent was seen as an "expert". One of his most popular sayings was: "we are blinded by what we think we know; disbelieve if you can". He was to become one of the key

[1] *Holmes (1944).*

people to convince his fellow geologists of the reality of Continental Drift.

In the early 1950s Carey began to clash with some of the major opponents to Continental Drift. One of the most well-known opponents was Sir Harold Jeffreys, a widely respected English geophysicist, who was knighted in 1953. Carey saw an opportunity to disprove Jeffreys's claim that the fit across the South Atlantic "was a bad misfit" when Carey's former chief in the Anglo-Persian Oil Company, Dr. G.M. Lees, repeated Jeffreys's proof rejecting Continental Drift during his 1953 presidential address to the Geological Society of London. Carey sent Lees his rebuttal of Jeffreys's claim and Lees arranged for Carey's rebuttal to be published[1] by the Geological Society of London in 1955. It was a major blow for the opponents of Continental Drift.

Carey's attempt to prove that another of Jeffreys's claims was also wrong had been stopped in its tracks when a 1953 paper submitted to the Journal of Geophysical Research was rejected. Jeffreys had dismissed the concept of drift by stating that it was physically impossible for continents to move about the globe. Carey's paper proposed a mechanism of mantle convection essentially the same as that adopted today by Plate Tectonics but since the prevailing dogma was that the Wegener theory was wrong Carey's paper was rejected by the referees as "naïve". Two decades later, after Plate Tectonics was generally agreed, Carey dusted off his rejected paper and resubmitted it to the journal with the suggestion that they might like to publish it as an historical document. The editor replied their policy was not to publish a paper previously turned down, *"however good it might be!"*[2]

The 1956 Hobart Continental Drift Symposium

In March 1956 a small group of rebel geologists travelled to Tasmania, the island state of Australia perched at its southern tip. Their ultimate destination was the geology department of the University of Tasmania in Hobart to attend a geology symposium about the outrageous theory of Continental Drift.

Today Continental Drift has been rebranded as Plate Tectonics and it is the cornerstone of every geology course. In 1956 the outlook was very different. At the time Continental Drift was an idea that many established geologists, and indeed the whole scientific establishment, considered a theory that could be easily disproved. Continental Drift

[1] *Carey (1955).*

[2] *Carey (1988), p 104.*

was considered to be so outrageous that it was almost universally rejected and ridiculed. Only the brave (some would say foolhardy) geologists dared support the theory.

There was almost total rejection of Continental Drift in the Northern Hemisphere, but it didn't happen in the Southern Hemisphere, particularly in South Africa, India and Australia where a few hardy spirits continued to argue that Continental Drift answered a lot of geological questions.

Why was there this particular distribution of views? One reason may be that the geology in the Southern Hemisphere was radically different from the Northern Hemisphere. This was vividly impressed on the geologist Rhodes W. Fairbridge in 1946, then a young geological lecturer in historical and structural geology at the University of Western Australia. He found that,

> "all the best standard textbooks originated in Europe or America, but the geological history of the northern hemisphere seemed singularly in contrast to that of the southern hemisphere. It was like teaching Greek with a Latin textbook."[1]

Geologists in the Northern Hemisphere had carefully split the immense amount of geological time into geological periods. In between the geological periods there was a dramatic change in the fossils providing an easy method to separate out the different geological periods of time. But, as Fairbridge witnessed, the geology of the Southern Hemisphere didn't seem to fit this pattern.

> "In Australia we found that the main tectonic and sedimentational breaks in the record did not occur, as in the north, at or about the period boundaries. The Precambrian sedimentation runs right through to the Middle Cambrian; then there is an important orogeny and the sedimentation is resumed, jumping across the Cambrian-Ordovician boundary. And this happens repeatedly through the geological record, with orogenies in late Ordovician, middle Silurian, middle Devonian, late Carboniferous, middle Triassic, lower Cretaceous."[2]

Perhaps then it was no wonder that important new text books and science papers incorporating the Continental Drift point of view were issued in India, South Africa and Australia. Maybe the best known book, *Our Wandering Continents: An Hypothesis of Continental Drifting*[3], was written by Alexander du Toit in 1937. After his death the

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[1] *Fairbridge (1964), p 61.*

[2] *Fairbridge (1964), p 62.*

[3] *du Toit (1937).*

geological Continental Drift "baton" in South Africa passed on to Lester C. King who wrote important papers in the 1950s continuing to promote the theory of Continental Drift.

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By the early 1950s Carey had become well-known for inviting many leading geologists to symposia to unravel the geological history of Tasmania and these in turn lead to many invitations to address leading conferences in Australia and overseas. So in March 1956 Carey was confident enough to convene an international symposium on Continental Drift at the University of Tasmania in Hobart.

Some of the strongest opposition to Continental Drift in the world at that time was in the United States and especially at Yale University, so Carey invited the chairman of the Yale University geology department, Professor Chester Longwell, to the Hobart symposium as the principle guest. Longwell had participated in the 1928 symposium in America that had conclusively rejected Continental Drift and joined in many debates since then. He was well known for his agnostic views and was widely respected for his rational views on the subject. Longwell's conclusion at the time was that the theory of Continental Drift was not proved but not disproved either. He could be counted on to give all the evidence a fair hearing.

Several participants were invited to present papers about the evidence that ancient fauna indicated the continents were joined in the past. Professor Lester King, from the University of Natal in South Africa, was invited to present a paper reassembling the Arctic and North Atlantic before the continental breakup and also discuss the great sub-oceanic ridges on the sea floor. A young newly qualified geophysicist, Ted Irving, was invited to discuss the new evidence for Continental Drift from rock magnetism. As some of the leading exponents of Continental Drift began to assemble for the first talk we can imagine that a certain sense of excitement was in the air. A scientific revolution was about to unfold.

A well-known promoter of Continental Drift

Carey had invited Lester King, although his views were often not welcome in other geology departments. The previous year King had visited New Zealand and Stevens remembers the outrage.

> "Lester King visited New Zealand in 1955 and offered to give a lecture at Victoria. I well remember the discussion that ensued [the

> head of the geology department, Bob Clark, was] absolutely adamant that King would not be allowed to publicise his crackpot ideas on Continental Drift in HIS department!! Eventually a compromise was arrived at and Lester King gave his lecture to a capacity audience in one of Victoria's large lecture halls (in the Biology building, not Geology!). On his part King gave a masterly lecture, supposedly on geomorphology, but with a large measure of Continental Drift thrown in, in the guise of the landscape evolution of the Gondwana continents. As Lester King rolled out the Gondwanaland story with great aplomb Bob Clark's face was a study!!"[1]

Another geologist, John Dewey, remembers he was convinced by King's description of Continental Drift. As he recalled nearly half a century later:

> "Lester King, of the University of Cape Town, travelled the globe after World War II proselytizing for Continental Drift. As an undergraduate in London in 1956, I heard him talk in Imperial College, clearly and convincingly, when I became convinced that Continental Drift must be a reality."[2]

Carey's presentations

By far the longest paper presented was by Carey himself. Carey was in advance of many of his colleagues at this conference and he showed just how much of seafloor spreading could be envisaged. He described several crucial elements that today are accepted as essential to global tectonics but at the time needed to be described in detail. The concepts were so new he even had to name them. Later workers would either be ignorant of Carey's names, or simply ignore them, so they were renamed. Today, although Carey's names are different, the descriptions of the features are strikingly familiar.

Carey's megashear is a large strike-slip fault that cuts through the ocean crust and is known today as a transform fault. A rhombochasm is a gap in the ocean crust created as the crust moves apart. Today it would be known as a diverging ocean construction zone. The gap is "occupied" by new oceanic crust. The "rhombo" part of Carey's name indicates the gap has parallel sides but a triangular gap in continental crust was given the new name sphenochasm. This triangular gap can be created by the rotation of one continental block with respect to the

[1] *Stevens (1988) p33–34.*

[2] *Dewey (2015).*

other. An orocline is a once straighter orogenic belt that has been bent by rotation.

Once Carey had defined all those new geological features he could explain that none of these structures can develop in isolation. An orocline implies a sphenochasm on one side of it because it cannot go on diverging indefinitely. It must end against a megashear or perhaps another orocline. A megashear must either go right around the globe or begin and end at oroclines or rhombochasms. A single structure of this scale implies a chain of other structures to absorb the implied movement. All this was startlingly new and it took years before other geologists started to discover what Carey already knew in 1956.

Continental Drift at Lamont-Doherty

Back in the Northern Hemisphere, at the newly formed Lamont Geological Observatory, the concept of Continental Drift had been causing a headache for two geologists. Bruce Heezen and Marie Tharp were both working at Lamont Geological Observatory in the early 1950s just as the study of the ocean floor became exciting. Before then the ocean floor was a dark and mysterious place but the new technology of echo sounding soon revealed some of its hidden mysteries. Bruce Heezen and Marie Tharp had both been recruited by Maurice Ewing, although in totally different circumstances.

Maurice Ewing was the first Director of the Lamont Geological Observatory, later renamed Lamont-Doherty Earth Observatory in honour of a major gift in 1969, and was almost universally known simply as "Doc" by his colleagues. As a young geophysicist from Lehigh University in the 1930s he had become known for his pioneering work in seismic refraction studies and research of the ocean floor. In the early 1940s, the U.S. navy asked him to help with their sonar equipment. Ewing and his colleague Joe Worzel discovered that temperature effects were bending the sound waves in such a way as to create a shadow zone where a submarine could hide. By the end of the war the U.S. navy was convinced they needed to know what was under the oceans and funds began to flow generously into American Laboratories. Ewing created the Lamont Geological Observatory at Columbia University and became its first director. The work at this institution focused on physical oceanography using underwater sound, magnetics for detecting submarines, bathymetry of the seafloor, and seismology to study how earthquakes and shock waves travelled through the Earth. In 1947 Ewing needed bright young graduates to work in oceanography and began a lecture tour

with the avowed purpose of finding the right people to help him explore the ocean floor.

One student Ewing found was Bruce Charles Heezen, who had been born in 1924 in Vinton, Iowa. When Heezen was first introduced to "Doc" Ewing he surprised the 23 year old by asking him, "Young man, would you like to accompany me on an expedition to the Mid-Atlantic Ridge? There are some mountains out there and we don't know which way they run." Heezen was so startled by this question that he didn't immediately answer. Fortunately his professor said, "Of course he would like to go!"[1] This affirmative answer meant Heezen spent the next thirty years as a geologist who specialised in the ocean floor.

Another young recruit was Marie Tharp who was born in 1920 in Ypsilanti, Michigan. She attended more than a dozen different schools and by 1939 Tharp had begun classes at Ohio University. During the war years in 1943 she began to study Geology at the University of Michigan, finally obtaining a Masters in Geology and a Bachelor's in Maths. By 1948 she was applying to Ewing for a job but at first he struggled to see what task he could possibly give her. It must have crossed his mind to send her to sea, but the sea was a dangerous place in the 1940s. Just how dangerous the sea was became obvious a few years later on the morning of 13th January 1954. Lamont's research ship, Vema, was starting her third voyage when it began running before a nasty winter gale between Cape Hatteras and Bermuda, pitching and rolling violently. The drums on deck began to rumble back and forth and four men, Maurice Ewing, his youngest brother John Ewing, Charles Wilkie and Michael Brown, attempted to secure the drums before they were washed overboard. Suddenly a freak wave swept all four men and the barrels into the sea. Ewing said afterwards that he suddenly became part of an emulsion of men, oil drums and sea water. He heard a man call, "Doc! Help me", but he could see no one. All he could see was waves. Later he surmised that this must have been Charles Wilkie, just before he drowned. By this time Vema was about a mile away. With a masterful display of skill the captain brought the ship around and managed to rescue the remaining three men, first John Ewing, and then Michael Brown and Maurice Ewing who were clinging to the same oil drum.[2]

Sending Marie Tharp to sea must have seemed out of the question. After some thought, he asked if she could produce drawings. Fortunately she confirmed she had taken a course in draughting so was immediately given the job of producing copies of maps and

[1] *Tharp, Frankel (1986).*

[2] *A more complete account of this story is given in the book, "The Floor of the Sea" by William Wertenbaker. See between pages 130 - 133.*

diagrams. She became one of only a few women in the male dominated world of geology.

It wasn't immediately obvious that Heezen and Tharp would eventually form a close team. Heezen was employed as Lamont's principal investigator of echo sounding. He mainly acted as a consultant for companies such as the American Telephone and Telegraph Company, Cable and Wireless Limited and a number of others. In 1952 Tharp joined the same team as Heezen and was given the job of converting the mass of echograms into a much more understandable form by converting the information into a pictorial representation of the ocean floor. Tharp was so good at her job that she was soon in great demand. She could convert a mass of squiggly lines into a visual representation of what was actually there and everybody wanted her to work on their data. She soon began to feel the strain and Ewing gave Heezen the task of resolving the situation. He responded by deciding that she should only work on his data.

In 1952 Marie Tharp noticed something amazing as she began to build up the first pictorial picture of the ocean floor that anyone had ever seen. In three of the transatlantic profiles there was an unmistakable notch in the Mid-Atlantic Ridge that looked like a continuous rift valley. It looked like there was one gigantic crack in the ocean floor where it was splitting apart. She told Bruce Heezen but he refused to believe it.

The problem was that the unmistakable notch in the Mid-Atlantic Ridge looked distinctly like Continental Drift, a concept that was rejected as totally absurd by virtually all American geologists. According to the widely dismissed theory of Continental Drift the mighty Atlantic Ocean had been caused by the continents of North American and Europe drifting apart. Heezen was so confident the notch couldn't exist that he indignantly corrected Tharp's map by erasing the portions of the maps that didn't make sense. Tharp responded by pelting him with bottles of India ink.[1]

Heezen's mind was changed when a plot of Atlantic earthquakes was being prepared the next year. It was noted that the proposed rift valley was in the same vicinity as the earthquakes. The epicentres of the earthquakes all followed the line of Tharp's proposed rift. They reasoned that if there was a connection between earthquakes and the rift it would be possible to simply plot the position of the rift around the world using the earthquake epicentres already available. The data

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[1] *See National Geographic 125 Years: Legendary Photographs, Adventures, and Discoveries That Changed the World: Epic Journeys, Landmark Discoveries, Photographs That Changed the World.*

all fitted. By mid-1953 Heezen finally became convinced that a world encompassing rift valley existed on the ocean floor.

Nearly three decades later Tharp recounted the same story in a short article called *Mappers of the Deep*[1] published by the American Museum of Natural History in October 1986. As she recalled, "In 1952, I became convinced of the valley's existence along a segment of the ridge. Within about six months Heezen agreed and began to wonder about its significance." She also noted that much of the data obtained by the German Meteor expedition, from 1925 to 1927, had remained an untapped source of information for many years. Nobody, for example, ever bothered to connect all the "holes" found in the numerous sounding profiles along the crest of the ridge. If someone had made the connection, the central rift valley might have been discovered then and there."[2]

Once Heezen was convinced that the rift was real he had to tell his boss Maurice Ewing, the director of the Lamont Earth Observatory. Tharp recalled that Heezen, "told Ewing of our discovery soon after he accepted it himself."[3] Ewing realised that this discovery was so profound, if true, that they needed to collect firm evidence of its existence before anyone else was told. The proclamation came down that no one was to be told about the existence of the continuous rift valley. By the time the Continental Drift Symposium was being held in Tasmania the information was just about to be released.

It's perhaps easy to imagine why the rest of the world weren't told about this rift for years. The whole idea that there was a rift encircling the world continually splitting the continents apart seemed too incredible to believe. The presentation of the evidence needed to be carefully prepared if the rest of the world were to accept it. There were plenty of opportunities to publish their conclusions but it remained a closely guarded secret and no one outside of a very small group ever found out about this ground-breaking concept. As Tharp later recounted in 1986:

> "[Any knowledge] of the existence of the rift valley remained within the confines of Lamont until February 1956, when Bruce first presented the idea at a symposium organized by Harry Hess, professor of geology at Princeton University, for the National Academy of Sciences. Bruce brought along one of our globes with the rift valley outlined in bright red. The valley was at least on our globe, if nowhere else, and hard to miss. Hess was impressed and

[1] *Tharp, Frankel (1986).*

[2] *Tharp, Frankel (1986).*

[3] *Tharp, Frankel (1986).*

> invited Bruce to Princeton to elaborate on the discovery. The first published account of our find … did not appear until 1956 at an American Geophysical Union meeting in Toronto, at which Ewing and Bruce announced the discovery of a seismically active rift zone at the crest of the Mid-Atlantic Ridge and its extension into the Arctic and Indian oceans and African rift valleys."[1]

It seems most other scientists were completely unaware that this discovery was about to be announced in multiple science journals in 1956. It was broadcast to the world that Lamont scientists had discovered a worldwide rift 2 miles deep, 20 miles wide and 40,000 miles long. It was such a remarkable discovery that it stimulated further research into the ocean floor for decades to come. One paper by Ewing and Heezen described how:

> "Oceanic ridges of the Mid-Atlantic Ridge type are believed to be continuous over great lengths. They apparently have the median rift zone as a characteristic feature throughout, and this rift zone is the locus of the shallow focus earthquakes. The ridges may be traced through poorly sounded areas by the aid of an epicenter map. It must be borne in mind that the rift zone may be the primary feature in this combination and the ridge simply a consequence of the rift."[2]

Various abstracts by Heezen and Ewing mentioned "a great mid-ocean ridge" and how this system seemed to continue onto land in the active rift zone of Africa. The first map of the ocean floor of the North Atlantic presented by Heezen and Tharp in 1956 also showed the rift as a continuous feature on the ocean floor.

The information was finally well and truly out and the media quickly spread the news of the great new discovery. A map of the world-encompassing rift valley had even appeared in the *New York Times* by February and soon everyone was talking about the important new discovery. Heezen gave a talk about the existence of the world-encompassing rift system in Guyot Hall at Princeton on the evening of 26th March 1957. At the end of Heezen's talk the chairman of the university's geology department, Harry Hess, is reported to have stood up and said in essence, "You have shaken the foundations of geology".[3] The new discovery was a media sensation and Bruce Heezen and Marie Tharp had become its stars.

The almost unbelievable discovery of a giant rift valley circling the world created disbelief in many circles but it was soon confirmed from

[1] *Tharp, Frankel (1986).*

[2] *Ewing and Heezen (1956), p 80.*

[3] *As reported in Continents in Motion by Walter Sullivan, p 57.*

an unexpected source. Jacques Cousteau, a famous underwater explorer of the time, hadn't believed in the rift valley so he had taken movies with a camera mounted on a sled, the Troika, dragged behind his ship. The pictures he recorded convinced him that the ridge was real. As Marie recalled, the film was shown during one geological congress.

> "[It was shown to] a large evening audience as an unscheduled event at the congress. On his film, the great black cliffs of the rift valley, sprinkled with white glob ooze, loomed up through the blue-green water. I think that Cousteau's movies may have convinced a few doubters at a critical time that our rift valley was really there."[1]

A Tour of America

Due to the success of the Hobart Continental Drift Symposium Carey had been invited to come to Yale as visiting professor for a year. This took some time to organise but during the academic year 1959 to 1960 he delivered complete courses in structural geology and global tectonics at Yale. He also lectured in many other American Universities, mostly under the American Geological Institute Visiting International Scientist Program. The American institutions he visited in that year included well-known academic institutions of Columbia, Harvard, Brown, Wesleyan, Lehigh, Princeton, Duke, North Carolina, Louisiana State, St. Louis, Cincinnati, and Ohio State. In Canada he lectured at Toronto, Western Ontario, McGill, Calgary, and British Columbia.

Carey was invited to debate Professor Walter H. Bucher, the patriarch of American tectonicists, at Columbia. The Schermerhorn Theater was packed as geologists and geophysicists gathered from far afield, and a most memorable night resulted.

As well as his lectures at Yale, Carey lectured several times at Princeton in late 1959 and early 1960, describing his concept of oroclines, the paleomagnetic evidence for large intercontinental movements, and ocean-floor growth by repeated insertion of paired slices at the mid-oceanic ridges. All this had already been detailed at the Hobart Continental Drift Symposium but Carey's passionate delivery ensured the lectures were packed. At the time Harry Hess, the chairman of the Princeton geology school, cemented a warm friendship with Carey.

The campaign to introduce Continental Drift culminated with a special session sponsored by the Society of Economic Paleontologists

[1] *Tharp, Frankel (1986).*

and Mineralogists at the annual meeting of the American Association of Petroleum Geologists at Atlantic City on April 25, 1960. Carey was lead speaker with Keith Runcorn, Ken Caster, and William Gussow on the panel. The hall was full, including the aisles and the walls. After the formal papers from the panel, the questions and discussion continued until long after midnight with few if any leaving, until the chairman had to terminate the meeting. At the end of his American tour Carey felt confident that "The revolution to continental dispersion had begun!"[1]

Carey had replaced John Rodgers at Yale for the academic year and a quarter of a century later Rodgers recalled:

> "My own contribution to the solution of this dilemma was negative; I left North America for a year to study the Alps. As a result, the Yale Geology Department could appoint a visiting professor for that year; we chose S. Warren Carey, and North American geology has never been the same since. He travelled all over the continent, he lectured in his inimitable now-you-see-it-now-you-don't style, he talked to anyone who would listen, and when he was through, no-one could laugh off Continental Drift anymore."[2]

The Bullard Fit

By 1966 it had been over a decade since Carey had published his reconstruction of South America-Africa clearly showing that there was a remarkable fit between the continental shelves of the two continents. Despite this Sir Harlod Jeffreys, the widely respected English geophysicist, was still denying there was any close fit and was arguing this in the science journal *Nature* and other places. In 1964 he had again dismissed the continental fit as unreal in the Journal of the Royal Astronomical Society. Then, Sir Edward Bullard (a fellow of the Royal Society), J.E. Everett and A. Gilbert Smith, from the Department of Geodesy and Geophysics at Cambridge, published a paper, *The fit of the continents around the Atlantic*, that fully confirmed Carey's fit using the latest computing power then available. The paper described how,

> "The approximate fit of the coastlines of Africa and South America has been noticed by many writers and formed an important part of the evidence used by Wegener (1912, 1924) in support of his hypothesis of Continental Drift…

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[1] *Carey (1988), p 119.*

[2] *Rogers (1985).*

> Carey (1958) was the first to show that the fit of Africa and South America is much closer at the continental edges than it is at the coastline. In spite of this, Jeffreys has expressed a total disbelief in the reality of the fit; he says (1964): "l simply deny there is an agreement." The reason for this scepticism is not clear; perhaps it is connected with doubts about the accuracy of Carey's fits carried out on a globe provided with moveable transparent caps.
>
> The matter is clearly important and the purpose of this paper is to put the facts beyond doubt by using the best data available and finding the 'best fits' by objective arithmetic methods. …
>
> The area studied includes North and South America, Greenland, Europe and Africa. Africa and South America were first fitted, then a second block was assembled from North America, Greenland and Europe; the closeness of these fits exceeded our expectations and fully confirms the work of Carey."[1]

Several maps were provided in the paper illustrating the remarkable close fit between the continents. One of these maps, showing all the continents reconstructed as the ancient supercontinent, was widely reproduced and the fit became known as "The Bullard Fit".

Towards the end of the 1960s the science innovators had finally begun to convince most of their more conservative colleagues that the continents had split apart over hundreds of millions of years. It had taken more than 50 years of rejection and ridicule. By 1967 Continental Drift was rebranded as Plate Tectonics and a new scientific revolution was declared. Some years later Bullard wrote a candid article, *"The Emergence of Plate Tectonics: A Personal View"* discussing in part why the science revolution took so long.

> "To think the whole subject through again when one is no longer young is not easy and involves admitting a partially misspent youth... Clearly it is more prudent to keep quiet, to be a moderate defender of orthodoxy, or to maintain that all is doubtful, sit on the fence, and wait in statesmanlike ambiguity for more data."[2]

We might naively think that all the scientific innovators would be hailed as great scientific thinkers once the mainstream finally accepted the new scientific revolution. But that didn't happen. The scientific innovators who had brought about this revolution in the Earth sciences now believed there was an even more astonishing revelation about the Earth. Carey, Heezen, Tharp, Holmes, King, Fairbridge and

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[1] *Bullard, Everett, Smith (1965).*

[2] *Bullard (1975).*

a number of others all presented evidence that the Earth had expanded in size over the last few hundred million years.

FROM CONTINENTAL DRIFT TO EARTH EXPANSION

Perhaps one of the most intriguing aspects of our hidden history is just how close the scientific innovators came to convincing their conservative colleagues to accept Earth expansion in the 1960s.

In 1961 *Time* published a *Life Pictorial Atlas of the World* (Fig. 1). The publication was an oversized table top book containing over 590 pages in full colour. In the foreword the editors described how ever since it was first discovered that the world was round mankind had fashioned replicas of the terrestrial sphere set in the immensity of the universe. The book used the most authentic replica globe ever made that appeared in scores of photographs throughout the *Life Pictorial Atlas*. The atlas was designed not only as a valuable collection of reference maps but also a provocative guide towards understanding man's world in the space age.

The *Life Pictorial Atlas* included a dramatic series of globes to illustrate the latest theory that the Earth had gradually grown in size. The full text accompanying the illustrations of the geological globes explained the concept in greater detail:

> "**The Changing Earth**
>
> The globes on this page illustrate one theory of the evolution of the continents. Graduated in size (from top to bottom) and dated from about 500 million years ago to the present, they also illustrate the theory that the Earth itself has grown in size since the very beginning of its existence. The expanding-globe theory suggests that the Earth began as a mass of cold radioactive dust which gradually warmed up over aeons. It began to expand, fracturing its relatively light crust and creating thousand-mile-long ridges that sundered existing land masses. The present-day shape of the continents seems to suggest that some of them were once joined together. It can be seen that South America and the west coast of Africa, for example, closely resemble related pieces of a gigantic jigsaw puzzle (bottom globe). Evidence based on the nature of the Earth's rock layers and shifts of the polar icecaps seems to confirm

the theory that all of the present-day continents were in radically different relationships to each other in times past *(top three globes)*."[1]

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In 1964 a collection of invited geological papers were published as a book, *Advancing Frontiers in Geology and Geophysics*, by the Indian Geophysical Union. This volume was in honour of Professor M.S. Krishnan, a geologist and geophysicist of some standing and international reputation, as a celebration of his sixty-fifth birthday and with the hope that the volume would be a useful addition to the literature of Earth Sciences.

Several of the invited papers discussed the radical theory of continental drift within their general framework. A few discussed it in detail: J.T. Wilson's paper was entitled, *Submarine Ridges as a key to the*

[1] *From: The Life Pictorial Atlas of the World (1961).*

Fig 1. *The Life Pictorial Atlas of the World, a coffee table book published in 1961 by Time Incorporated. It is open where a dramatic series of globes illustrated the changing Earth over geological time, illustrating how the Earth might have looked at 500, 180, 30 million years ago, with a final illustration of the Earth as it is today. The text explained how the globes had been deliberately graduated in size to illustrate the theory that the Earth itself has grown in size.*

pattern of the motion of Continents since Triassic Time and L.C. King's paper was *Polar wandering or Continental Drift?*

One of the invited papers was about Earth expansion; *Thoughts about an Expanding Globe*, by Rhodes W. Fairbridge from Columbia University, New York City. This paper's abstract described how,

> "Recent developments in the exploration of ocean basins suggest that they are largely of youthful origin, and floored by basaltic crust, isotope dates of which are exclusively Cenozoic. Theoretical consideration of the Gravitational Constant, of mantle-core evolution, of its geodetic consequences due to mass displacement in the crust, polar shifts, and paleo-geographic development, all converge to support a concept of a geologically youthful expansion of the globe."[1]

He explained how a number of geologists and geophysicists had already reached similar conclusions starting from different points of view.

> "O.C. Hilgenberg (of Berlin) from a morphological viewpoint (1933); Havemann from rotational differences between core and mantle (1952); L. Egyed (of Budapest) from a dynamic consideration of the Earth's interior (1956a, 1957), and on paleogeographical grounds (1956b); S.W. Carey (of Tasmania) from a reconstruction of continents in the style of Wegener (1958); J.T. Wilson (1963) on geotectonic grounds; and Bruce Heezen (of Lamont Geological Observatory) on the basis of the form and nature of the mid-ocean rifts (1959, 1962). A Russian interpretation was recently offered by Ivanenko and Segitov (1961)."[2]

Fairbridge proposed that the rate of expansion could be estimated by considering that the ancient Earth was a "proto-crust wherein all the continental units are joined, and all ocean basins eliminated". He had constructed his own model using "a round basket-ball bladder" that was inflated to 30 cm in diameter with continental units glued to the bladder in their present position. The bladder was then slowly deflated to 20 cm diameter.

> "In this way almost all the ocean areas disappeared and the 'continents' came together; an exception remained in the central and western Pacific, which, much reduced, still remained as open area (fig. 5). No further reduction in size was possible without

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[1] *Fairbridge (1964).*

[2] *Fairbridge (1964). N.B. Hilgenberg's initials were incorrectly given as O.O. in the original publication but have been corrected in this quote.*

disengaging segments and 'forcing' a considerable continental drift."[1]

Fairbridge's "fig. 5" were sketches of an expanding globe taken from his experimental rubber model. The sketches had originally been prepared for the *Life Pictorial Atlas of the World* published by *Time* in 1961.

Carey's discovery of Earth expansion

By far the most well-known geologist to discover Earth expansion was Carey. The concept was all very new for him in the 1960s. It was at the 1956 Continental Drift conference he had organised in Tasmania that he first realised that a smaller diameter Earth resolved many of the problems he saw with Continental Drift.

During the 1940s and early 50s Carey found that he had increasing difficulty in reassembling the continents on an ancient Earth as his reconstructions of the continents became more accurate. Wegener's concept was that all the continents of the ancient Earth must have been joined together in an ancient Pangaea but as Carey made accurate reconstructions he found it was impossible to reassemble all the continents together without introducing a gap in the reconstruction.

During the 1950s Carey had made a 30 inch diameter scale model of the Earth to investigate the fit of the continents during continental dispersion. This reconstruction was what disproved Jeffrey's claim of a poor fit between Africa and South America. Yet, using moulded plastic film also confirmed that it was impossible to assemble Pangaea without a gap appearing on its perimeter somewhere. However he reconstructed Pangaea there was always a gap that appeared, extending from the perimeter right to the centre. The gap looked like a slice of pie that someone had stolen. What was this gap? (See Fig. 2: Carey's early reconstruction).

At an early stage in his investigations Carey went to some pains to ensure that he compared and transferred shapes and sizes of the continental blocks accurately. He spent years accurately plotting large projections for Africa and South America, including every piece of the Earth's crust. He combined this with spherical tracings from the globe on his specially built spherical table. He tried to reconstruct the continents in multiple ways but was frustrated to find he could never construct a whole Pangaea. He could easily reconstruct any particular sector he chose but could never continue the reconstruction around

[1] *Fairbridge (1964).*

the whole globe. If he started from South America and continued around the world by the time he reached Indonesia there was a yawning gulf to Australia even though he felt sure from the orocline mountain building region that Idonesia and Australia belonged together. Yet if he started from Australia and Indonesia he couldn't close the Arctic.

Carey had produced detailed reconstructions of many of the areas around the Pacific and these indicated that Australia had been closer to many of its neighbouring continents in the past. He had separately restored the regions around Alaska, Japan, south-east Asia, and the Philippines.

Carey wasn't particularly happy with the global reconstruction he presented at the Hobart Continental Drift Conference that showed all the continents reconstructed together as one land mass. He called it a "Draft assembly of Pangaea" doubtlessly to indicate that he thought it still required adjustment. In this reconstruction he only managed to join all the continents together by leaving a large gap between Eurasia and Australia. This was a gap that he knew could never have really existed because his separate detailed reconstructions showed how Eurasia and Australia had been connected. Carey wasn't satisfied with the reconstruction and the other participants also discussed the large gap in Carey's global reconstruction. Edmund D. Gill, from the National Museum of Victoria in Australia, gave a talk about the distribution of life in the Lower Devonian period and described how the similarity of fossils at that time indicated that South Africa and South America were joined. He agreed this indicated Continental Drift was true. On the other hand, Carey's reconstruction presented at the conference showed that Victoria and the Southern Shan States were even further apart in the past. It was clear Carey's draft assembly of Pangaea had produced radial gaps separating those regions that the local geological and fossil history tied together. The Lower Devonian faunas indicated these two land masses were joined just as closely as they are today so Gill wondered "why South-East Asia was not nearer to Australia in view of the similarity of their Lower Devonian faunas."[1]

During these symposium discussions Carey suddenly realised that his reconstructions of Pangaea merely required a smaller diameter Earth to remain connected. He had become so frustrated that he had been tempted to abandon the whole assembly but suddenly the reason they didn't fit became clear. It wasn't his method that was at fault, but his assumption that the Earth was the same size as the Earth of today. The assembly of Pangaea was not possible on an Earth of the present radius but on a smaller radius globe those difficulties vanished. By the

[1] *Carey (1958), p 114.*

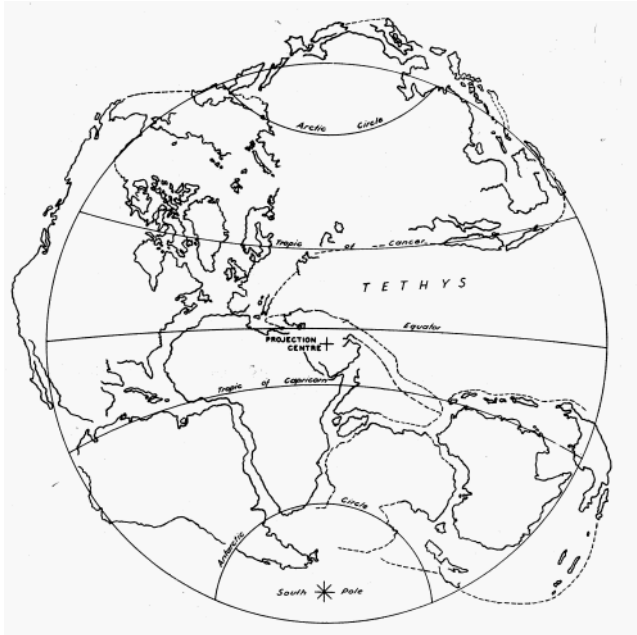

Fig 2. *Carey's draft assembly of Pangea submitted at the 1956 Continental Drift Symposium meeting. Plate tectonic reconstructions would adopt virtually the same configuration nearly a decade later but rechristen it the "Bullard Fit".*

end of the symposium he had realised that "a coherent integral assembly is only possible on a globe of smaller radius."[1] The years of work attempting to reconstruct a constant diameter model suddenly combined with other anomalies to convince Carey that the reconstructions could never work for the whole globe. By varying the diameter of the Earth the gap could gradually be reduced in area until it disappeared completely.

Heezen discovers Earth expansion

The whole concept of a world wide rift was also causing Bruce Heezen problems in the late 1950s. What was causing this expanding rift? If these same rifts were found in the Pacific then it almost seemed that the whole world needed to be expanding. Heezen first wrote about the problems and his proposed solution of expansion in 1958 but he must have been considering it for some time before then. It seems likely he was also one of the independent discoverers of Earth expansion.

In 1958 Heezen gave his first published talk on the subject of Earth expansion. In the audience was one of his close colleagues, Henry

[1] *Carey (1977).*

Menard, who later recounted in his own book, *The Ocean of Truth*[1], that his impressions of the speech could be fairly summarised by the talks abstract:

> "The major question involved in continental displacement remains the forces of displacement. If the original hypothesis of Taylor that all the continental blocks are moving toward the North Pacific is true, then the extensional features of the ocean basins' floors could be well explained, unless, of course, the North Pacific turned out also to be under extension. In this case we would be forced to assume an extension of the ocean floors in general. Since the North Pacific seems to differ in no fundamental way from other ocean floors it seems necessary to reject the Taylor thesis. Our other alternatives are to assume all the continents are being compressed to compensate for oceanic extension or to appeal to an expansion of the mantle perhaps by a phase change at the core mantle boundary. This latter hypothesis has been little considered by geologists and in view of the arguments presented in this paper seems worthy of more serious investigation."[2]

Menard noted that the talk cited no references even though everything quoted above had already been published in very similar form by Carey. He formed the impression that,

> "Heezen was in the process of becoming yet another independent discoverer of the expansion hypothesis. Even his main figure resembled Carey's cartoon of ridge development. My own memories are that Bruce was talkative about the possibility of an expanding Earth but that he lacked any strong convictions in the period from 1958 to 1960."[3]

Heezen pointed out that continental displacement can be accommodated in two very different ways. The first by Continental Drift, in which continental blocks float on and move through the denser ocean floor. In this case there should be compression across one side of the continent and extension right along the opposite side. The second by expansion of the interior of the Earth, where the solid and differentiated crust breaks up until the individual blocks become separated by the insertion of newly derived mantle material. In this case there should be extension in all oceanic zones. The continental margins of all the coasts of the continents seemed to give evidence of extension. It seemed to Menard that Heezen not only seemed to be

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[1] *Menard (1986).*

[2] *Heezen (1959a).*

[3] *Menard (1986), p 149.*

unaware of Carey, he also seemed unaware of the other suggestions about Earth expansion at that time.

Heezen presents expansion at the 1959 International Oceanographic Congress

In the summer of 1959 Bruce's father died and on returning to New York a month later he had his first heart attack. He spent three weeks in hospital and recovered just in time for the International Oceanographic Congress in September. This was the first of its kind and Bruce wasn't going to let a weak heart hinder him. He presented thirteen papers covering a range of aspects on the exciting new discoveries about the ocean floor. One of the talks discussed Earth expansion.

Heezen's talks received much coverage in the press but his talk about the concept of Earth expansion received even more attention, not all of it complimentary. On the ninth day of the conference, 8th September 1959, the New York Herald Tribune headline was, *Earth Seen Expanding Like Ripening Orange*. The Tribune article began,

> "Dr. Bruce C. Heezen of Columbia University has stirred up his fellow oceanographers with an 'outrageous hypothesis'. The Earth, says the thirty-six year-old research associate, has been expanding over the millennia as if it were a slowly ripening orange."

That description of the expanding Earth was not really how Heezen envisaged it but the Tribune went on to explain how the theory had been a major talking point at the conference,

> "All week long the delegates at the International Oceanographic Congress meeting here pondered on Dr. Heezen's speculations… One said: 'It explains all the facts beautifully, but I can't believe it. Do you believe it, Dr. Heezen?' Another, in a major speech today, commented: 'We know so little about the problem of the continents we should not reject even the idea of an expanding Earth.' Another simply cried: 'Impossible.'"

Menard noted later in his own book that it seemed to him that this second talk on expansion presented at the International Oceanographic Congress in 1959 was 'bolder in advocating expansion' than his first had been in 1958. Unfortunately he also noted that by the time the printed version was published Heezen appeared less enthusiastic and 'the printed word said no more than the following':

> "The location of the Mid-Oceanic Ridge, oft cited as a remnant of the original continental rift, opposes Continental Drift since it seems to require that the continents drift in several directions at the same time. A possible way out of this dilemma is to postulate an expanding Earth; but, in view of the meager evidence now available, this may seem too drastic and may itself have other more serious objections of astronomical nature."[1]

It seemed that Bruce Heezen was already starting to learn to be nervous about how much he said about Earth expansion in public.

Carey's Expansion Theory in America

As previously mentioned, Carey delivered complete courses detailing his concept of Continental Drift and Earth expansion at many American and Canadian Universities during the academic year 1959 to 1960. During this exhausting lecture tour Carey was also able to refine Earth expansion. The English cosmologist Paul A.M. Dirac had proposed in 1937 that the Universal Gravitational Constant[2], denoted by a large G, should vary over the age of the universe. It should become less as time progressed, implying that everything should weigh less as time went on. This would imply that the Earth would have also have expanded because the minerals within the Earth would have been able to relax and change to less dense forms throughout the age of the Earth.

Dirac's idea of a reduction in large G was taken up by Professor Robert Dicke, of Princeton physics school, and Professor C. Brans who developed this concept further in a series of papers beginning in 1957. Knowing that this concept would be of interest to Carey, Harry Hess invited Dicke to visit Yale in 1959 to discuss the geological evidence for expansion. Carey soon realised that "the amount of expansion from decline in G was less than [he believed] had occurred, and its distribution in time was different."[3] Carey reasoned that change in large G couldn't be the cause of the large amount of expansion he saw.

Carey tells us that the expanding Earth theory did win some approval: "some seeds did fall on fertile soil and took root, only to be choked off later when subduction weeds grew rank".[4]

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[1] Heezen (1959b).

[2] This large Universal Gravitational Constant, G, is sometimes confused with the gravitational attraction on the surface of the Earth, which is denoted small g.

[3] Carey (1988), p 141.

[4] Carey (1987), p118.

Bruce Heezen proposes expansion in Scientific American

Bruce Heezen's next publication mentioning the expanding Earth was in the *Scientific American* journal in 1960. His main theme was to describe the gigantic sinuous rift system and evidence for large-scale Continental Drift but after presenting the material he then compared the data to the various hypotheses available to explain the phenomenon observed. He compared it with classic Continental Drift, mantle convection drift (the term Plate Tectonics hadn't been proposed yet) and Earth expansion. For Earth expansion he noted that:

> "In an attempt to overcome this dilemma I have recently suggested that the Earth is neither shrinking nor remaining the same size; rather, it is expanding. If the Earth were expanding and the continents remained the same size additional crust would have to be formed in the oceans. This is apparently just what is happening in the mid-ocean rift valleys."[1]

Heezen discussed the amount of expansion required. Although a recent paper in *Nature* by Wilson had limited this expansion to a very low level Heezen believed that it was possible for phase changes in the Earth's core to cause a large expansion so that continents "once covered the entire surface of the smaller Earth with an unbroken shell of granitic material." In essence he was stating that a small expansion as envisaged by Wilson didn't explain the features he saw.

Arthur Holmes considers Earth expansion

Arthur Holmes decided to leave Edinburgh University and formally retire in 1956 when he was sixty-six. In the same year of his retirement both the Geological Societies of London and America presented him with their highest awards for his "outstanding accomplishment in geology". On his retirement Holmes immediately started to revise his geological text book, *Principles of Physical Geology*. It turned into a mammoth task taking him the rest of his life. The second edition[2] was almost three times the original first edition and was finished just a few months before he died in September 1965.

Having achieved such outstanding acclaim as an early originator of what was soon to renamed Plate Tectonics, perhaps most people

[1] *Heezen (1960).*

[2] *Holmes (1965).*

would have avoided including anything controversial in his new book, but Holmes wasn't most people. Holmes's active intellect was still seeking to unlock new mysteries of the Earth right up to his death. His new interest was the Expanding Earth theory. In many ways this concept must have seemed like a replay of his earlier interests in the revolutionary subjects of the Age of the Earth and Continental Drift. Once again it must have crossed his mind that it might be prudent not to include such a controversial theory in the new edition of his book. But once again he did include it.

In the first edition of his book *Principles of Physical Geology* published in 1944, Holmes had added a complete chapter about Continental Drift. By 1965, he had moved on to include a chapter about Earth expansion and described how,

> "There is now ample evidence for seriously considering the hypothesis that expansion of the interior of our planet may have played a dominant role in geological history and the evolution of surface features."[1]

Holmes's chapter provides a snapshot of many of the pioneers of Earth expansion in 1965. He describes how a South African astronomer, J.K.E. Halm, had challenged the traditional faith in Earth contraction by considering stellar evolution. Halm proposed in 1935 that the Earth's original density was considerably higher than it is now. If the atoms were closely packed they might lose some or all of their electron shells to allow the density to rise to abnormal figures. This phenomenon reaches its limit in white dwarf stars. If this original density of the Earth was higher at that time the ancient Earth would have been smaller. In 1940 J. Keindl had also returned to the idea of a slow expansion of the Earth caused by the degeneration of high density material over time.

Holmes also described the work of the German geophysicist Ott C. Hilgenberg in detail. Hilgenberg had shown in his 1933 book, *Vom Wachsenden Erdball*[2] (The Growing Earth), how terrestrial expansion would bring about the splitting and gradual dispersal of the continents as they moved radially outward during geological time, while upwelling from the mantle would fill up the gaps to increase the area of the ocean basins. A schematic illustration based on Hilgenberg's detailed globes indicated the effects of expansion of the Earth's interior on the original crust. The primordial continents were stretched and then fragmented, until they gradually separated as they moved apart due to the Earth's increasing volume. Hilgenberg also

[1] *Holmes (1965), p 965.*

[2] *Hilgenberg (1933).*

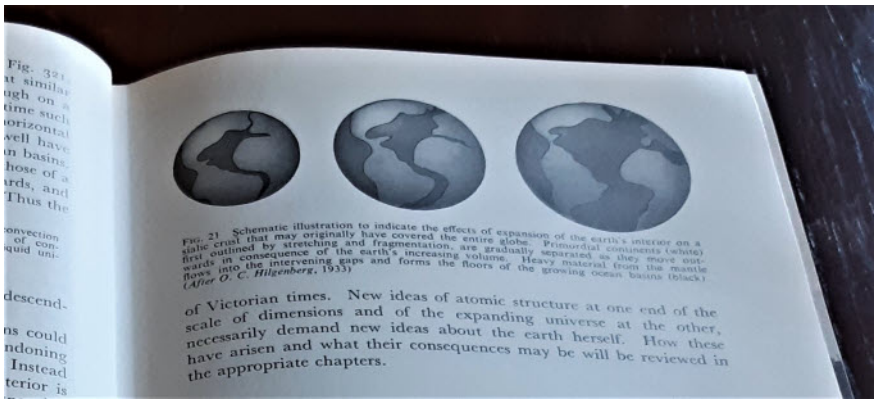

Fig. 21 Schematic illustration to indicate the effects of expansion of the earth's interior on a sialic crust that may originally have covered the entire globe. Primordial continents (white) first outlined by stretching and fragmentation, are gradually separated as they move outwards in consequence of the earth's increasing volume. Heavy material from the mantle flows into the intervening gaps and forms the floors of the growing ocean basins (black). (*After O. C. Hilgenberg*, 1933)

of Victorian times. New ideas of atomic structure at one end of the scale of dimensions and of the expanding universe at the other, necessarily demand new ideas about the earth herself. How these have arisen and what their consequences may be will be reviewed in the appropriate chapters.

Fig 3. *The 2nd edition of Holmes' highly popular geological text book published in 1965. It is open at the page with a schematic illustration showing the effects of Earth expansion (after O.C. Hilgenberg, 1933). Holmes devoted a chapter to discussing The Expanding Earth and offers an excellent snapshot of thoughts about Earth expansion in the mid-1960s.*

had a different mechanism for the cause of expansion, proposing that the interior of the Earth had increased in mass as well as volume.

A Joint Statement about Expansion

The early 1960s were a very turbulent time for Bruce Heezen and Marie Tharp. At Lamont there were widely different opinions evolving about the ocean floor. At first Maurice "Doc" Ewing preferred the conventional fixist view of no Continental Drift which had been the established view for the last 50 years. As more data came in from the research ships he reluctantly started to move towards the opposing continental dispersion view. The most extreme view in his mind was the expansionist view that the continents were being forced to drift apart by Earth expansion. Ewing found he could never agree this was remotely possible. It seemed almost inevitable that the controversy would eventually lead to a breakup of the working relationship between the team of Heezen and Tharp, and their boss Maurice Ewing.

Eventually the relationship between Ewing and Heezen broke down completely in a very public and spectacular fashion. Heezen had been on the research ships at least once a year since he joined Lamont in 1947. But then, in 1958 he was denied access to any ships. Even his friends weren't sure why. Menard gained the "impression that he had had a heart attack and was barred from sea for that reason." But on

the other hand, in 1958 he had "emerged from hospital, given 13 papers at the Congress, and changed a flat tire one night while driving home. So the heart attack did not keep him from sea in 1960 and 1961."[1] Worst was to come. Heezen was officially cut off from all the data the ships were providing. No data would mean no more maps of the ocean floor could be produced. Heezen and Tharp found an enterprising solution to overcome this particular problem. During the early 1960s the data they needed to complete their maps of the ocean floors was provided by "midnight requisitions" when everyone else had gone home.

Menard recalled how there was an "unusual joint statement" that hinted at the increasing tension between Heezen and Ewing and also clarified the reason for the strain. First the statement explained the ideas they both agreed on,

> "The present authors have concluded that the rifted-mid-ridge is dominated by extensional deformation"

but then noted their differences,

> "…However, each favor a different primary mechanism of the deformation in their estimates of the amount of extension indicated." Ewing "favors a mechanism drawn by mantle convection, while Heezen … believes that the extension results primary from the internal expansion of the Earth."[2]

They couldn't have made it any plainer. Heezen was remaining adamant that the Earth had expanded even when his boss told him it hadn't.

Heezen and Ewing's "unusual joint statement" appeared in the scientific paper, *The Mid-Oceanic Ridge and Its Extension Through the Arctic Basin,* which was published in the *Geology of the Arctic* in 1961. By this time this very public falling-out not only meant that Heezen was denied access to the Lamont ships or its data, it also meant his ability to play an active role in the rapid developments in the Earth sciences in general, and the further development of his ideas about expansion in particular were very effectively stopped. One historian who studied this period in detail is H.E. Le Grand, from the Department of History and Philosophy of Science in the University of Melbourne, and he describes in his book *Drifting Continents and Shifting Theories* how,

> "Heezen became a virtual spectator on the 'revolution' occurring around him and he did not further articulate the brief sketches of the Expansionist program he had already given".[3]

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[1] *Menard (1986), p 199.*

[2] *Heezen and Ewing (1961).*

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Although Heezen found he had been virtually stopped from researching into Earth expansion he still tried to write about it, particularly in some British publications. Keith Runcorn edited a collection of papers that were published in the book *Continental Drift*[1] in 1962. In this assemblage of essays workers in several fields of Earth science considered the hypothesis in the light of current evidence and concepts. Rapid advances in the study of palaeomagnetism received particular emphasis and the several principles and methods involved in this study were outlined. These were all trying to solve the problem of seafloor spreading and Continental Drift from varying theoretical viewpoints. Dietz spoke on seafloor spreading, Heezen argued for spreading and drifting on the surface of an expanding Earth, Vening-Meinesz proposed the convection model, and Vacquier restated his arguments that offsets of magnetic anomaly patterns showed large-scale lateral displacements of the seafloor. Although they all agreed that continental dispersion had occurred there were differing explanations to account for it.[2]

Heezen supposed that expansion was caused by a volume enlargement within the core of the Earth. It was this volume increase that had forced the ancient crust to split, separating the super continent, while the space between the continents was filled with new mantle material. This explanation separated the enlargement process in the core from the process occurring in the mantle.

Heezen and Tharp's Paper in the 1965 Symposium on Continental Drift

As part of a 1965 symposium on Continental Drift Bruce Heezen and Marie Tharp were able to report on their investigations of the Atlantic and Indian Ocean floor. The paper by Heezen and Tharp, still officially from the Department of Geology and Lamont Geological Observatory in Columbia University, was entitled *Tectonic fabric of the Atlantic and Indian oceans and Continental Drift*[3]. It began by reviewing the new studies of the ocean floor around the Indian Ocean. Most of the paper was a review of the new features discovered on the ocean

[3] *Le Grand (1988), p 224.*

[1] *Runcorn (1962).*

[2] *See Le Grand (1988, p 201) for a discussion of this book.*

[3] *Heezen and Tharp (1965).*

floor but tucked away at the end of the paper was the observation that these seemed to indicate that the Earth was expanding.

> "A simple convection current pattern is not favoured for the explanation of these features. The tectonic pattern of the Indian Ocean floor seems particularly difficult to explain in terms of oceanic spreading. Although there are many unsolved problems and some evidence which apparently is adverse to this concept, the writers believe that a general expansion of the Earth better explains the sea floor tectonic fabric than the recently popular convection current hypothesis."[1]

The Harassment

Until this point most of the antagonism to ideas about Earth expansion had been directed towards Heezen. However, the closer collaboration between Heezen and Tharp soon meant that she began to feel some of the hostility.

In 1965 Heezen was requested to urgently see Ewing and Worzel and told that he would be requested to "leave Lamont on July 1, 1965, if he did not "change his ways". He was told "you know what we mean".[2] Heezen said he didn't know what they meant. Tharp was the next to feel Ewing's displeasure and it became so constant Heezen and Tharp eventually began to refer to this period as The Harassment. Later it became apparent, after consulting a lawyer, that Heezen couldn't be fired because he had tenure as a professor, although he did find that he has been prohibited from spending any of his grant money. All payments for equipment, supplies, service, travel and personnel had been stopped. Without control over his own grants he would be unable to pay anyone's salary, including Tharp's when she worked on the maps of the ocean floor. In 1965 Tharp underwent surgery and began working from home while she recuperated. She never returned to Lamont, seemingly preferring the remoteness from Lamont.

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The pressure soon started to affect how much Heezen and Tharp were prepared to admit in public.

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[1] *Heezen and Tharp (1965).*

[2] *Felt (2012), p 157.*

In 1966 Heezen and Tharp published another paper about the Indian Ocean Floor, *Physiography of the Indian Ocean*[1]. The observation that Earth expansion explained the data better was gone.

Heezen was also feeling the restrictions of not being allowed to use the Lamont data. After the annual meeting of the American Geophysical Union held in Washington on 17 - 20 April 1967, Heezen expressed some of his frustration to Menard. He told him that Menard's own talk was one, "he wished he had given himself. It was, in fact, just the kind of analysis that he would have done had he not been forbidden to use Lamont data."[2]

Hilgenberg – Palaeomagnetism on an expanding Earth

Many people seem to think that Ott C. Hilgenberg only produced one book in 1933 about Earth expansion but that is far from true. In practice Hilgenberg remained convinced the Earth had expanded and continued to work on the concept for decades. The major hindrance to further progress was the monumental events conspiring to prevent him from developing the concept much further.

By the time his *Vom Wachsenden Erdball* book was published in 1933 he had a young daughter and he was pleased to be appointed as a regular assistant to the TH Berlin Institute of Kinetics in 1934. Unfortunately, this was also the time when the Nazi party began its rise to power in Germany. When Hilgenberg refused to join the Nazi party out of principle he automatically relinquished any possibility of further promotion within the department.

By the beginning of World War Two in 1939 Hilgenberg was working as a consultant for international literature in the fields of natural sciences and engineering at the Berlin TH library. As the war progressed he was interrupted by frequent calls from the city's defence and air-raid warning service. During the Battle of Berlin in 1945 Hilgenberg was drafted to defend the university and in the fighting that ensued he was shot. The bullet lodged in his left upper arm and for a long time afterwards his arm remained paralysed. After the fighting was over all the streets were blocked with rubble so he was forced to walk through the underground train system until he reached Ruhleben Station at the western terminus of the underground train line.

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[1] *Heezen and Tharp (1966).*

[2] *Menard (1986), p 286.*

After the war Hilgenberg was fortunate to receive extra food rations for his family since he was considered a "brain-worker" because of his scientific publications. From 1945 to 1946 he travelled into the Soviet occupied zone many times to recover thousands of library books belonging to the Berlin TH. He also worked on his thesis, *Die Bruchstruktur der sialischen Erdkruste* (The Faulting Structure of the Earth's Sialic Crust) and was awarded his Dr. Ing. degree at what now became the Berlin Technical University (TU). With the worsening political situation he became unemployed in 1950 and remained unemployed except for the odd job offered by the government's work creation measures or when he sometimes found work as a free-lance scientist at the Berlin TU. This employment at the university also enabled him to continue to publish various scientific papers about geological and physical subjects.

By the late-1950s Hilgenberg had been following the results obtained from the new palaeomagnetic data with great interest and had noted the results reported in the 1956 Hobart Continental Drift Symposium and elsewhere. He was particularly interested in the 1960 suggestions by Eyged, about using the palaeomagnetic data to determine ancient radius, and an ensuing 1961 debate in *Nature* between Carey, Cox and Doell.[1] He believed he could add to the discussion and began to look at the new results being extracted from palaeomagnetic data to see if he could throw new illumination on the problem of expansion.

Many of Hilgenberg's publications were in German but in July 1962 he outlined his thoughts in English and these were published in September as a paper, *Rock Magnetism and the Earth's Palaeopoles*[2], in the science journal *Geofisica pura e applicate*. This journal was later rebranded as *Pure and Applied Geophysics* and continues to publish original scientific contributions in the fields of solid Earth, atmospheric and oceanic sciences.

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In 1966 Hilgenberg published another paper continuing the theme in even greater detail: *Die Paläogeographie der expandierenden Erde vom Karbon bis zum Tertiär nach paläomagnetischen Messungen (The palaeogeography of the expanding Earth from the Carboniferous to the Tertiary period as evidenced by palaeomagnetic data)*[3]. This paper was written in

[1] *Carey (1961).*

[2] *Hilgenberg (1962).*

[3] *Hilgenberg (1966).*

German but the abstract was provided in multiple languages: German, French, Russian and English. The English abstract read:

> "The palaeogeography of the expanding Earth from the Carboniferous to the Tertiary period as evidenced by palaeomagnetic data: The purpose of this article is to show that the geography on six model globes, e.g. the distribution of the sialic continental blocks and of the simic ocean floors on these model globes, is in agreement with most of the data given by E. Irving in his lists of palaeomagnetic directions and pole positions until the end of 1968. This is shown in thirty-six photographs of Earth model globes for the Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and Eocene periods, the globes having diameters equal to 69%, 72%, 75%, 78%, 84%, and 92% respectively of the present diameter of the Earth. For the time in question about 350 mean declinations and inclinations at sites scattered over the whole Earth were taken from these lists and used in plotting about 125 great circles on the six globes, each great circle having two poles and two equatorial points. These poles and equatorial points are in complete agreement with the chosen distribution of the ancient continents and with the chosen proportions of the Earth's expansion."[1]

The paper was a comprehensive appraisal of the evidence that the palaeomagnetic results collected so far fitted an expanding Earth better than a constant-sized Earth. The paper, complete with detailed tables and diagrams of the palaeomagnetic data covered over fifty pages and included detailed globe reconstructions showing the positions of the poles. The article started with a detailed discussion of the method of determining the position of the poles on an expanding Earth using palaeomagnetic data. Then the problems encountered when the magnetic data was fitted to a constant-sized Earth were reviewed and how these disappeared once expansion of the Earth was assumed. All the palaeomagnetic data obtained by various workers was then presented in a table and the palaeomagnetic data was used to reconstruct the poles on detailed representations of the globes. The globes for the different ages were displayed on various pages: the Permian (Perm-Modellglobus), the Carboniferous (Karbon-Modellglobus), the Triassic (Trias-Modellglobus), and finally the Jurassic (Jura-Modellglobus) globes. The movement of both the North and South poles over time was reconstructed from all this data and shown on two maps covering the period from the Precambrian to the Eocene.

[1] *Hilgenberg (1966).*

The Newcastle Symposium of 1967

In 1967 the NATO Advanced Study Institute funded an event organised by the School of Physics at the University of Newcastle upon Tyne, from 29 March to 4 April. The director of the School of Physics at the University of Newcastle was Professor S. Keith Runcorn. Amongst the more well-known names of the time who contributed an article to the event were Robert Dicke from Princeton, Lazlo Egyed from the Geophysical Institute, Ted Irving from the Dominion Observatory, Pascual Jordan from Univerität Hamburg and Neil Opdyke of Lamont Geological Observatory.

Two years later, the proceedings were published as a book entitled, *The Application of Modern Physics to The Earth and Planentary Interiors*[1], with Runcorn acting as editor. One of the main themes addressed by the conference was the subject of Earth expansion. In fact these expansion papers are the first papers listed in the report of the proceedings of the symposium.

Other people were present who didn't have any papers published. "Professor K.M. Creer" was thanked because he "contributed greatly to the planning of the programmes of sections". Creer was well-known by then for producing maps illustrating Earth expansion after he had discussed it with Carey. We also know from other sources that Hilgenberg was also invited to present a paper and travelled there in his Volkswagen Beetle car, but he doesn't have any papers listed in the published proceedings either. In fact he is never mentioned in the report of the event apart from one oblique reference in one of the other papers. Even this reference fails to note he had first published about Earth expansion over three decades previously, before some of the participants were even born.

The symposium considered the hypothesis of Earth expansion first in several separate sections. The first section about expansion considered the theoretical considerations about a varying Universal Gravity with papers by Gilbert, McVittie and Roxburgh. The next section addressed the problem of detecting a change in Universal Gravity with contributions by Kanasewich, Savage and Runcorn himself. The third section looked at the theoretical aspects of the hypothesis of Earth expansion with contributions by Jordan, Egyed and Beck. The final section looked at the geological and geophysical evidence related to expansion with contributions by the Termiers, Dearnley, Irving, Van Andel and Hospers.

The two Termiers clearly outlined the problems of expansion by starting their article with the observation that,

[1] *Runcorn (1969).*

> "All palaeographical arguments that are, in general, in favour of Continental Drift are also in favour of the hypothesis of the Earth's expansion." Although it was relatively easy to "reconstruct the primitive continental assemblage … we meet many difficulties with the Tethys, some of them being inherent in the notable difference in the relative orientation between Eurasian and African axes with regard to their present ones … if the Earth's diameter is constant."[1]

Having considered various clues such as Banded Iron Ores, Ocean regressions and Glaciations they concluded that,

> "at all events global palaeogeography does not display any arguments against Earth expansion."[2]

Holmes had died only a few years before the symposium, so Dearnley was still influenced by his appraisal of expansion. He quoted Holmes's conclusion that:

> "'there is now ample evidence for seriously considering the hypothesis that expansion of the interior of our planet may have played a dominant role in geological history and the evolution of surface features' (Holmes, p. 965)."[3]

Runcorn was a close colleague of Creer, who had reproduced his own expanding Earth reconstructions after discussing it with Carey, and he thought that "Viewing Creer's reconstruction purely as an observation, unencumbered by questions of the effect of its acceptance on theories of the Earth's evolution, it appears striking but, hard to evaluate". He was obviously struggling to come to terms with what he was seeing but he reasoned:

> "Creer has carefully evaluated a previous observation that the continental blocks, now covering about a quarter of the Earth's surface, would fit together rather well as a complete spherical shell on a globe of radius of about a half of the present one. Some objection could be raised to the method by which the blocks are bent to accommodate a smaller radius of curvature and, of course, there is an arbitrary element in the choice of the edge of the continental shelf, although there is no doubt that the 500 fathom isobath is a better boundary to the continental blocks than the present coastlines. The fit of Europe and North America and South America and Africa is so good that it has been accepted as among the most convincing arguments for the drifting apart of these continents and the goodness of the fit — the exceptions, Iceland

[1] *Runcorn (1969), p 87.*

[2] *Runcorn (1969), p 101.*

[3] *Runcorn (1969), p 103.*

> and the Niger delta, are post-drift — accords with the recent time (5% of the Earth's life) of this Continental Drift episode. The fit Creer finds of the other continental boundaries is less good but, as he supposes this shell to have been disrupted soon after the Earth's origin, this reconstruction of the globe 4000 million years ago seems plausible. To suppose this fit corresponds to the situation an order of magnitude more recent in time, as Cary and Heezen have argued, results in a very rapid rate of expansion (0.5 to 1 cm/year) and raises insuperable difficulties about the Pre-Cambrian history of the Earth. On the other hand, to suppose the present shapes of the continental blocks have been substantially unchanged for 4 - 5 eons is equivalent to rejecting the idea of the gradual separation of sialic material from the mantle, implicit in the theory of the growth of continents. It would be a view easier to accommodate if the Earth had once been molten and its differentiation a brief episode at its origin. …"[1]

Perhaps the main point to note is that Runcorn had convinced himself that any expansion, if it occurred at all, must have taken place in the remote past since to propose otherwise, "as Carey and Heezen have argued, results in a very rapid rate of expansion … and raises insuperable difficulties …"[2]

Dearnley noted that "over the past decade there have been a number of proponents of the hypothesis of an expanding Earth (e.g. Egyed, Carey, Dicke, Heezen), although there seems not to have been much agreement on the possible causes or the actual amount or rate of expansion."[3] But in the published papers from the symposium there wasn't any disagreement. They all followed Runcorn's thoughts that a fast rate of expansion raised "insuperable difficulties".

Egyed was clear that he was talking about the "slow expansion hypothesis" of expansion. He started by explaining that:

> "All the hypotheses have their empirical basis and can be supported by observations as well as by theoretical considerations. In the following we shall try to summarize the observations pointing towards an expansion of the Earth and amounting to an increase of 0.65 ±0.15 mm/year in radius. Furthermore, some theoretical basis of the expansion is suggested resulting in the same rate of radius increase and some consequences will be considered."[4]

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[1] *Runcorn (1969), p 48.*
[2] *Runcorn (1969), p 48.*
[3] *Runcorn (1969), p 103.*
[4] *Runcorn (1969), p 65.*

The concept of expansion itself had various lines of evidence that seemed to support the concept. He highlighted the fact that:

> "The expansion of the Earth offers the most simple explanation of the formation of the continental crust and oceanic basins. On this explanation, the primaeval Earth became a layered one by spherically symmetrical differentiation, and a uniform continental crust covering the whole surface was formed. The deviations of this surface from the level surface would show a Gaussian distribution. This primeval uniform crust disrupted under the effect of internal expansion, and along the fracture lines the emerging denser material of the deeper parts controlled by isostasy occupied a level about 5 km deeper than the original crust, providing the base of the first oceanic basins. ... Many properties characterizing the continental and oceanic areas are plausible consequences of the above simplified mechanism, e.g. the double maxima of the hypsometric curve, reflected also in the frequency of the depth distribution of the Molto-surface data ...; the possibility of matching all the continents on a globe with a total surface area nearly equal to that of the continental areas; etc."[1]

Egyed was a well-known supporter of the slow expansion model caused by decrease in the gravitational constant and presented the case that there was empirical evidence "pointing towards an expansion of the Earth".[2] He explained how the continental crust would be fractured and illustrated this with photographs of the "fracture patterns, caused by the increase of internal pressure in layers of plaster solidified on an inflated football bladder".[3]

Egyed considered that the,

> "episode of Continental Drift started with the fracture system separating the more or less contiguous Gondwanaland and Laurasia into the main blocks of the actual continents. … Along the deep fracture zone a steady convection of material started as a consequence of the expansion of the Earth's interior, the mass transport adjusting the space deficiency arising from the density increase, and near the surface a megatumour was formed. The broken-up pieces of the original continental Pangaea found their way onto the flanks of the megaundulations."[4]

In his own article, Jordan repeated his arguments about the Universal Constant of gravity causing an expansion of the Earth and

[1] *Runcorn (1969), p 65.*
[2] *Runcorn (1969), p 65.*
[3] *Runcorn (1969), p 68.*
[4] *Runcorn (1969), p 71, p 74.*

recounted how he "became interested when his late friend Fisher in New York made the remark [about] a marked expansion of the Earth in the course of its history."[1] He also suggested his test to determine if the gravitational constant was slowly reducing over time:

> "Classical planetary astronomy — without radio echo — obtains precision measurements of angular coordinates with deviations of only about 10^{-7}; in radial coordinates there remained relative uncertainties of 10^{-4}. Using radio echos these uncertainties can now be reduced to about 10^{-6}. Only in the case of the Moon, by the application of orthogonal reflectors transported to the Moon and by the application of lasers, may corresponding uncertainties be reduced to 10^{-8} or even 10^{-9}, so that here is a further possibility to test Dirac's hypothesis by precision measurements"[2]

In support of this hypothesised reduced gravitational constant he also presented the evidence that the Earth was expanding, continuing further on:

> "Let us remember the sensational confirmation of Heezen's concept about the role of the oceanic rifts in the process of the spreading of ocean floors, by the investigation of magnetic anomalies of the ocean bottom parallel to these rifts (cf. Vine', and also Cox, Dalrymple and Doe). We can say now that this much discussed and doubted spreading has ceased to be any hypothetical process: it is a fact.
>
> Two different interpretational hypotheses are possible now.
>
> (i) If there is no expansion (R = 0), then there must exist some compensating compressional feature.
>
> (ii) If there is not sufficient compensation, then expansion R>0 must unavoidably be inferred from oceanic spreading."[3]

In support of expansion he also noted that the theory of Earth expansion predicted "two preferred hypsographic levels on the Earth, meaning the existence of a spatially constant thickness of sial."[4] In contrast to this prediction from expansion he found that with other theories,

> "No attempt at all has been made to explain this fundamental empirical fact—one has to state simply that in a large amount of literature even mention of this fact is lacking. From this lack of any attempt to explain the two-level situation we have to infer the

[1] *Runcorn (1969), p 55.*
[2] *Runcorn (1969), p 57.*
[3] *Runcorn (1969), p 57-8.*
[4] *Runcorn (1969), p 59.*

> impossibility of any explanation in such a manner that any plausible process might be invented which could generate this splitting of hypsographic levels—all known processes can only contribute to destroying it; no process has been invented in any form of hypothesis which would be able to restore it, after destruction, or to maintain it against damage; erosion especially would be totally unable to do so. Therefore also any change of this thickness in the course of geological time cannot have been performed: this thickness must be interpreted as a characteristic value of the structure of the Earth, determined in the primary steps of the Earth's formation, and never changed in later ages."[1]

To Jordan the only process that seemed to make sense was the formation of a complete layer of continent crust, the sial layer, which was then split apart by the expansion of the Earth. He considered that,

> "expansion of the Earth could only tear this sialic skin into separate lumps – oceanic areas originating between them."[2]

Other authors thought the slow expansion model was the only one that they could believe. Van Andel and Hospers concluded their analysis of Earth radii from palaeomagnetic data by concluding that,

> "it will be clear that an expansion rate as advocated by Egyed, [is] more plausible than the fast expansion rates advocated by Hilgenberg, Carey, van Hilten, and Heezen. These fast expansion rates must hence be considered as implausible."[3]

Beck attempted to calculate the energy changes in an expanding Earth and concluded this model,

> "immediately restricts the possible radial increase, using reasonable primitive density distributions, to less than 100 km. Thus on present-day knowledge radial increases of the order of 1000 km seem improbable but radial increases of the order of 100 km cannot yet be ruled out."[4]

At the end of his article Dearnley concluded that,

> "The combined results of each of these entirely different and independent methods of estimation suggest a relatively uniform rate of expansion of the Earth's radius of about 0.65 ±0.15 mm/year as far back as 4500 million years."[5]

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[1] *Runcorn (1969), p 59.*
[2] *Runcorn (1969), p 59.*
[3] *Runcorn (1969), p 121.*
[4] *Runcorn (1969), p 83.*
[5] *Runcorn (1969), p 109.*

Anyone who read the proceedings later must have thought that all the evidence was overwhelmingly in favour of a changing gravitational constant causing a constant small increase in the Earth's diameter over the lifetime of its entire history. Yet this isn't quite the complete story. Participants at the symposium might have thought it strange to note that Hilgenberg was invited to read a paper but it never appeared in the report of the proceedings. His daughter, Helge, clearly remembers that he attended the symposium and took nine of his globe reconstructions to the conference, although by the end of the symposium he must have wished he had never accepted the invitation. As his daughter later related:

> "In 1967 Hilgenberg was invited to a meeting of the NATO Advanced Study Institute in Newcastle-upon-Tyne, England, to read his paper: *Why Earth expansion?* Afterwards, several students helped him carry his nine globe models into his VW-Beetle, but began playing football with them, eventually destroying all of them. Hilgenberg was totally shattered to see his life-time work literally trodden on."[1]

In addition to the destruction of his globes Hilgenberg also found that his paper wasn't to be included in the published proceedings.

Why was Hilgenberg's paper[2] never published? The most obvious answer was because Hilgenberg had been promoting the same "fast expansion rates advocated by Carey, van Hilten and Heezen"[3] for over three decades by that point in time. That is exactly what his globes illustrated. He already had his paper prepared for publication but in the end the only people whose papers appeared were those who supported the concept of slow Earth expansion caused by a change in universal gravity.

We can easily surmise why the evidence for the fast expansion model of Earth expansion wasn't included in the written record of the proceedings. The convener and eventual editor of the papers presented at the symposium was Runcorn who was convinced "a very rapid rate of expansion … raises insuperable difficulties".[4] He simply didn't believe the fast expansion rate was believable, so any papers supporting the fast expansion model were edited out.

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[1] Hilgenberg, H. (2003). In Why expanding Earth? p 47.

[2] Hilgenberg (1967, 2015). N.B. Although the paper was not published in the official proceedings, Hilgenberg produced a copy of his paper in June 1967 and sent them to the attendees. In 2015 the paper was uploaded to the web with permission of his daughter. It can be downloaded from: https://dinox.org/abstract1967.html

[3] Runcorn (1969), p 121.

[4] Runcorn (1969), p 121.

To people who only had access to the book containing the published proceedings it must have seemed that there was virtually complete agreement about the rate of Earth expansion at the conference. Indeed this is the message most people repeated about expansion for the next few decades.

Bruce Heezen and Marie Tharp appear to Abandon Expansion

The Harassment directed towards Bruce Heezen and Marie Tharp continued for years. In November 1967, Ewing informed Heezen that he was "suspended from the Observatory" and his research grants would be administered by somebody else. By the end of January 1968 Heezen was suspended from all activities except direction of the work of his students. By April 1968 Tharp had been told her pay would be withheld unless she stopped working with Heezen on their maps of the ocean floor and moved back to Lamont. Heezen was once again asked to resign but instead called a lawyer and drafted a letter insisting he would not.

Considering his virtual banishment from Lamont for his beliefs it is perhaps surprising that Heezen continued to promote expansion at all. The reason seems to be that he failed to understand the deep antagonism against expansion and perhaps believed that it would all soon be forgotten. But after several years it must have become clear that it wasn't.

It would seem likely that Heezen eventually abandoned all hope of convincing his fellow geologists that the concept of expansion was real by the late 1960s. He started to say enough to make his colleagues believe he had renounced all support for the theory. Marie Tharp would later say that she considered it better to just show their fellow geologists what was on the ocean floor with their maps, so we can imagine that Marie Tharp would have advised Heezen that this was a better method than engaging in open conflict.

This dismissal of expansion appeared to placate many of his detractors and coincided with a reconciliation with Ewing. In April 1970, Ewing sent Heezen a letter saying that it was his "belief" that the suspension in place since November 10, 1967, "would be lifted." But while some constraints were lifted it was clear the problems weren't completely over and the letter continued, "… for the time being, you will not be appointed any administration duties." But in 1972 Ewing resigned as director of Lamont to found a new division of Earth and planetary sciences at the University of Texas, and any final restraints

left from The Harassment period vanished. Tharp continued to work from home and was rehired as a Lamont employee. Heezen was allowed on Lamont ships again and Tharp eventually joined him. There was also a new research tool in the form of small reconnaissance submarines that could carry scientists down to the ocean floor and Heezen was one of the first geologists on board eagerly looking at the ocean floor with their own eyes.

It seemed to many that the young rebel had finally recanted his early views of expansion. His conversion to the popular view was certainly helping Heezen's credibility as a leading geologist. The virtual banishment from ships had been rescinded and he was now back at sea doing the research he loved. His close friendship with Tharp had become even closer during the banishment years so many people considered them 'a couple'.

By 1974 Heezen and Tharp were working on a panorama of the ocean floor for *National Geographic* magazine showing the area around Antarctica and this was published in the 1975 *Atlas of the World*. That would prove to be the last map produced for the *National Geographic* magazine but it was far from the last map ever produced. A major project of a world map of the ocean floor was planned and started as an independently produced enterprise. But in June 1977 geologists were shocked to learn that Heezen had died suddenly of a heart attack while in a submarine near Reykjanes Ridge, Iceland. Tharp was on the research ship *Discovery* studying the Ridge from above. They had recently completed their work on their *World Ocean Floor Panorama* and each had proofs with them on their respective ships. Bruce Heezen was 53 years old.

The heartache of losing Bruce wasn't the final blow for Marie Tharp. They still had a number of projects unfinished that she fully expected to be able to complete as a final tribute to their work together. When she attended a committee meeting to discuss the work the chairman informed her that others were now taking over the projects. She left the meeting in a daze. Later a committee member came to her house and took all the in-progress maps, data, and contours that were to be transferred to other scientists – "it was forcibly stolen" she would say decades later, "I was crushed and crushed and crushed". A few years later she would also learn that she had been made redundant from Lamont. She didn't fight it.[1]

However, no one could stop the publication of the ocean floor map because it had been independently financed. Tharp continued with the map they had planned and the first copy of the *World Ocean Floor Panorama*, conceptualised by Bruce Heezen and Marie Tharp, rolled

[1] *See Felt (2012) for a more complete account.*

off the presses in May 1978. The mid-ocean ridge snaked across the Earth looking like a monstrous scar encircling the whole Earth just as Tharp and Heezen had first imagined it in the 1950s.

The panorama won Tharp and Heezen the Hubbard Medal from the National Geographic Society in October 1978, its highest award. Tharp dedicated herself to producing and selling copies of their maps worldwide, setting up and running Marie Tharp Maps. Their *World Ocean Floor Panorama* was bought by schools, colleges and universities worldwide and there were also many requests to reprint the maps in various text books. It seemed that the maps of the ocean floor were everywhere. By the 1990s the Library of Congress had decided to create a Heezen-Tharp collection and Marie began the task of transferring material. Today the collection is viewable online and a copy of the *World Ocean Floor Panorama* can be viewed and downloaded in high resolution versions from the Library of Congress.[1] A few years later the ocean floor map was made available on Google Earth as an overlay.

Tharp never explained what the map meant - her opinion was that the map should show what was there and others could argue about it. A few thought they saw hidden revelations about the Earth. Although by then the accepted geological theory was subduction on a constant diameter Earth, some people looked at the map and saw clear indications of Earth expansion. Larry Myers recalls that he saw a mounted 8 foot copy of the Heezen and Tharp World Ocean Floor map at the National Space Administration library in 1980. This map showed him that the "curved outline of the deep ocean trenches bordering Asia closely resembled the curvature of the western coast of North America, running from Kamchatka in the north down to the Mariana Islands". Further study of the map revealed other matches:

> "…the right angle formed by the Tonga-Vityaz Trenches near Samoa … neatly fitted into the bight of South America at 20° South. From Samoa, the trench turns southward and runs through New Zealand, connecting with the curving Macquarie Ridge in the south that had once wrapped around Cape Horn at 60° South.
>
> To me, this configuration was empirical proof that Asia and Australia once conjoined North and South America and Earth must have been only slightly larger than Mars is today."[2]

The panorama of the world's ocean floors also reveals other realities. Classic depictions of plate tectonics show new material forcing itself up at the mid-ocean ridges, then moving gently across the ocean floor

[1] *See https://www.loc.gov/item/2010586277/*

[2] *Myers (2015).*

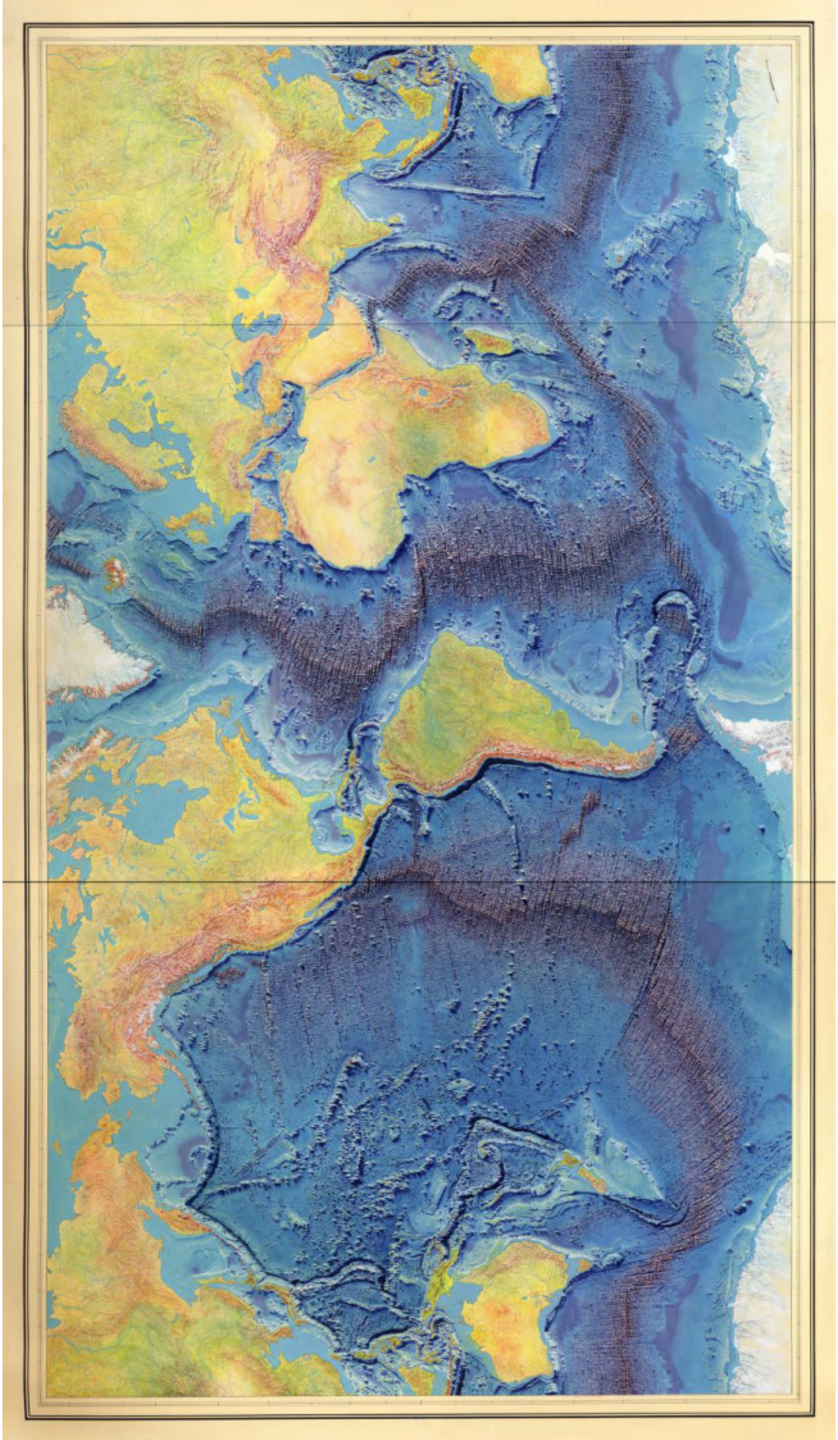

Fig 4. *The manuscript painting of the Heezen-Tharp "World Ocean Floor" map produced in 1978. This map was widely circulated as a wall map and has also been reproduced in many text books and articles. Today it is also available as an overlay on Google Earth. The Library of Congress has a copy in its Map Collections and a full size digital copy can be downloaded from the Library of Congress at https://www.loc.gov/item/2010586277/.*

until it is consumed again at a subduction zone. Yet looking at the world map it is obvious that the mid-ocean ridges are at least three times longer than any subduction zone – so how can subduction possibly work? The mid-Atlantic ridge is also too long for a non-expanding Earth – if the Earth had stayed the same size then the mid-Atlantic ridge should be the same length as it was when the continents first split apart, yet it is longer. All the mid-ocean ridges surrounding Antarctica are an even bigger problem since there is no subduction zone to swallow this newly-created material. Sediment adds another problem. Just off the coast of Alaska is a sediment plume, the Zodiac Fan, formed from the sediment of an ancient river system about 20 million years ago, clearly visible on the panorama. Unfortunately, plate tectonic theory insists that the plate wasn't there at that time. Only Earth expansion predicts that the plate would be exactly where the ancient sediment plume indicated. Jan Koziar's recent book, *Geological Proofs of Significant Expansion of the Earth and its broader scientific context*[1], discusses most of these observations in detail.

Looking back on those early years in which Continental Drift had gone from being an unacceptable idea to the cornerstone of science, Tharp was able to recall in 1986 how,

> "Continental Drift and Plate Tectonics are now accepted theories rather than heresies. The connection between the central rift valley and the movement of continents has become legitimate. And by the early 1970s, in a complete reversal, the disbelievers were the ones who were thought to have something wrong with them."[2]

By the early 1990s people were starting to understand just what a major revolution the maps had been. Tharp was interviewed by Ronald Doel in South Nyack, New York, on September 14, 1994, as part of an Oral History Transcript project. The transcript of the whole interview is viewable on the internet although interestingly the copyright notice insists that this transcript may not be quoted, reproduced or redistributed without written permission. Fortunately, we don't need to quote her exact words to get an impression of her memories. Tharp had difficulty in remembering some of the details that had occurred about three decades previously but she clearly recalled that everybody seemed very anti about the idea of expansion. A lot of articles came out in many journals against it, for one reason or another. It appeared to Tharp that it wasn't a set of philosophical reasons that motivated people but a set of genuinely physical problems with the concept of expansion. It seemed to her that the objections

[1] *Koziar (2018).*

[2] *Tharp, Frankel (1986).*

were mainly to do with heat and gravity, and most people believed it was just impossible for physical reasons. Because the Earth was supposed to be cooling off it should be shrinking, and getting all wrinkled as it shrunk, not getting bigger.

By the time of the interview in 1994 the concept of expansion had been virtually written out of most geological text books so some of the younger geologists must have wondered what this strange idea of Earth expansion might be. Later in life Marie Tharp was presented with awards from the Society of Woman Geographers, Woods Hole Oceanographic Institution and Lamont–Doherty Earth Observatory. But the most lasting memorial Marie Tharp left us is the *World Ocean Floor Panorama* - she not only conceived the map but spent decades ensuring it went out to schools and universities worldwide. One of her final acts was to ensure the map was *public domain* so everyone can study the ocean floor in detail.

An Essay Review of the Expanding Earth

By 1975 Carey was nearing the end of a long and successful career in geology. He had set up the Geology department at the University of Tasmania twenty-eight years previously and it was now a thriving department. In addition to his official doctor of science from the University of Sydney he had been awarded an honorary doctorate from the University of Papua New Guinea, been made an Honorary Life Fellow of the Geological Society of London, and had been a President of the Australian and New Zealand Association for the Advancement of Science. His 1956 Continental Drift Symposium at Hobart was widely lauded as a turning point in our understanding of the Earth and he had been awarded the Gondwanaland Gold Medal and the Clarke Medal for his researches on global tectonics.

Most people in ordinary occupations see retirement as an opportunity to spend more time on interests and hobbies. Carey had other plans. He saw it as a perfect opportunity to improve his fellow geologists' understanding of the Earth in general and the theory of Earth expansion in particular.

One of the first avenues Carey used to promote expansion was an essay in the *Earth Science Reviews* published by Elsevier Scientific Publishing Company. His article was *The Expanding Earth – an Essay Review* that covered thirty-nine pages of carefully reasoned evidence indicating that the Earth had expanded. His abstract introduced the extent of his thoughts at that time:

"The Wegener bombshell of gross continental separation promptly triggered the concept of Earth expansion as an alternative to drift, but books in German by Lindemann (1927), Bogolepow (1930), Hilgenberg (1933), and Keindl (1940) got little attention in the English literature. A second wave by Egyed (1956), Carey (1958), Heezen (1959), Barnett (1962), Brosske (1962), Neyman (1962), Creer (1965), Dearnley (1965), Jordan (1966), Sterner (1967), and Meservey (1969) ran against the orthodox tide, which, in geology, is lethal.

Discovery that pan-global oceanic rifts had palaeomagnetlc growth zones, and confirmation by JOIDES that all ocean floors are post-Palaeozoic, fit equally displacement or expansion models. The plate model combines ocean floor growth with "axioms" that orogenesis implies crustal shortening, that trenches are underthrusts, and that Earth radius is constant. All three "axioms" are probably invalid.

The plate theory has fatal falsities. Africa and Antarctica are ringed by expanding rifts and each should have post-Palaeozoic subduction zones to swallow more than 3,000 km of crust. These do not exist. This dilemma could be side-stepped by fixing one continent to its mantle, but escape is impossible with two such continents. The Permian equator now lies 37° north of the equator in North America, 40° north in Europe, and 17° north in Siberia, which is impossible on an Earth of constant radius without at least 6,000 km of post-Palaeozoic subduction within the Arctic. On the plate model the present Pacific must be smaller than the Permian Pacific by the combined area of the Arctic, Atlantic and Indian Oceans. Yet the continents round the periphery of the Pacific have all moved further apart in the direction of the Pacific margin. Meservey has shown the topological impossibility of progression from any Pangaea configuration to the present distribution of the continents except on an expanding Earth.

Phase-change from inherited metastable super-dense matter, change of G with time, and secular growth of mass at the expense of energy, have been offered as causes of expansion. These could be adequate, but raise other anomalies. Some new fundamental principles of physics may still remain to be discovered."[1]

[1] *Carey 1975, p 105.*

Carey's first expansion book – The Expanding Earth

Carey's next major promotion was his book, *The Expanding Earth*[1], published in 1976 by Elsevier Scientific Publishing Company. Carey's book was number 10 in a series of books about Developments in Geotectonics. It joined other books in the series with titles such as: *Global Tectonics and Earthquake Risk, Plate Tectonics, The Structure of the Earth's Crust* and *Recent Crustal Movements*. This was a serious geological publication with a highly detailed and comprehensive account of all the evidence indicating Earth expansion, complete with a reference list of over 820. The book was destined to encourage many people to research the concept of Earth expansion over the coming decades.

A Royal Society of Tasmania lecture

On 2nd of May 1977 Carey gave a talk to the Royal Society of Tasmania called *A Philosophy of the Earth and Universe*. He started with a look into the past,

> "My first address to this Society was thirty-two years ago in this hall, on Tasmania's place in the geological structure of the world. What I said then was contrary to the beliefs of the overwhelming majority of the geologists of the time. Today it is the commonly accepted dogma throughout the world. But during the intervening decades I have added to that concept of continental dispersion the still more radical proposition of accelerating expansion of the Earth. So once again I am the odd man out.
>
> Like Kipling's cat that walked by itself, the way of the loner is much harsher than the smoothed path of those who walk in the mutual admiration society of the orthodox. Bondi (1960 p.6) has pointed out that whereas we should seek economy of hypotheses, there is nevertheless a widespread tendency not to count assumptions implicit in the currently accepted doctrines, and so to excise with Occam's razor a new alternative which involves no more assumptions than the popular concept. Unfortunately, scientists being human, much more severe demands and ill-founded rebuttals, even slurs ad hominem, are approvingly thrown at the unorthodox loner.
>
> Disheartening as it has been to have one's best work rejected by the academies on such grounds, nevertheless, the painful process has in the long run been beneficial, like the torturous forging and

[1] *Carey (1976).*

> tempering of steel. For throughout the decades I have been forced to dig deeper and deeper into fundamental assumptions and "axioms", first of geology, then of all science, to the ultimate source. From this quest has slowly emerged a new philosophy of the universe, which is the subject of my address tonight. Before delving into this ultimate subject, first I should tell you briefly why I am convinced that the Earth is expanding, when so many of my colleagues think differently.
>
> For it was my need to explain the dispersion of the continents which led me to Earth expansion, and my need to explain Earth expansion, and that ancient rocks did not demand substantially greater gravity acceleration, which forced me to examine the assumptions of cosmology, and thence, the origin of the universe."[1]

With his introduction out of the way he reminded his listeners that virtually all geologists,

> "now agree that all the continents have separated … Most geologists assume that the radius of the Earth is virtually constant… Up to a quarter of a century ago, I too made these assumptions; until it became increasingly clear that this explanation led to fatal paradoxes when applied to the whole Earth, and that Earth expansion at an accelerating rate was inescapable."[2]

Carey then repeated some of the key arguments he had already outlined in much greater detail within his recent paper and book on expansion.

Although Carey was convinced that the evidence clearly showed that the Earth had expanded he described how "critics demanded of me a physical explanation of the cause of such gross expansion before they could take it seriously, even though their own model lacked adequate physical base." Carey was of course referring to the well-known fact that the mechanism of mantle convection was far from resolved. Was ocean crust pushed into the Earth or was it pulled? It is a problem that is still present today in Plate Tectonics. Carey's own expansion model had lead Carey to the most fundamental question of all - "the origin and evolution of the universe itself". Carey's own solution was the Null Universe model. In his conclusion Carey summarised his thoughts,

> "Commencing with a universal void, the inseparable twins of positive and negative charge, of north and south polarity, of momentum vectors and cancelling momentum vectors, of rotation

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1 *Reprinted Carey (1978).*

2 *Reprinted Carey (1978).*

> and counter rotation, of inertial mass-energy and gravitational potential energy, gravitational attraction and cosmological repulsion, have waxed wider with time, with increasing entropy and mean temperature, but always reduce to zero in the ultimate reckoning. For how else could the immensity of the universe come into being?
>
> When the Indians invented zero to make a continuous series of numbers from minus infinity to plus infinity the concept was so obvious that we marvel that it had not been thought of before. So also the universal null emerges with obvious simplicity, as inevitable."[1]

Carey's lecture was written up and published in the Papers and Proceeding of the Royal Society of Tasmania in 1978. At the end of this publication Carey was able to add a final fascinating postscript to his original talk.

> "Since delivering this address I have found that Edward P. Tryon had published in *Nature* of December 14, 1973 a universal null hypothesis under the title, 'Is the universe a vacuum fluctuation?' Tryon concluded that the universe did appear from nowhere about 10^{10} years ago, and to be consistent with the laws of physics the net value of all conserved quantities must be zero. His universe is homogeneous, isotropic, and closed, and consists equally of matter and anti-matter. Tryon also pointed out that inertial mass and gravitational potential energy are intrinsically equivalent and mutually cancelling. He also quotes Bergmann's argument that a closed universe must have zero total energy, because it would be topologically impossible for any gravitational flux lines to go outside the limits of the universe, and hence the sum of the energy of the whole universe must be zero."

The Geological Society of London hosts a debate about the Expanding Earth theory

On Wednesday 17 January 1979, the Geological Society of London and the Association for Geophysics hosted a joint debate entitled, *An expanding Earth?*

The meeting was a deliberation about the geological evidence for Earth expansion, with four speakers. The speakers had been chosen to present a balanced view of the evidence. Two speakers gave evidence against the theory of Earth expansion while the other two

[1] *Reprinted Carey (1978).*

gave evidence supporting expansion. The outline of the talks can be surmised from the four talk titles. The first talk was by A.D. Stewart entitled; *Quantitative limits to palaeoradius*. The second was by S. Warren Carey; *The expanding Earth*. Keith Runcorn, who was convinced "a very rapid rate of expansion … raises insuperable difficulties"[1], gave the third talk entitled; *A geophysicist's view of the expanding Earth hypothesis*. The final talk presented was by Hugh Owen[2]; *Ocean-floor spreading patterns do not support the constant dimension Earth*.

Robert Muir Wood wrote an article discussing the expanding Earth meeting, which appeared in the 8 February 1979 edition of *New Scientist*. Anyone who had attended the meeting could easily have wondered if this was really the same meeting. The *New Scientist* article depicted the debate as a one-sided promotion of Earth expansion, only mentioning Carey and Owen while ignoring Stewart and Runcorn. Wood reported,

> "With the idea that when things get sleepy you bring on the magicians and clowns, the Geological Society recently convened to discuss 'The expanding Earth theory', or EET. Proposing the notion were a bombastic Tasmanian professor of geology (Warren Carey) and a less flamboyant English geophysicist (Dr Hugh Owen)".[3]

Wood seemed to be outraged anyone could even consider the Earth might be expanding. He later complained that the meeting, "…was held at the Geological Society and publicised with press releases as if some important breakthrough was to be announced."[4] but he soon "…realised that the character who had lost contact with the ground was in fact the distinguished 19th century science of Geology."[5]

Carey submitted a reply to *New Scientist*, rebutting the few objections in the article, but the science journal ignored Carey.

Third edition of "Holmes's book"

When the second edition of Arthur Holmes's geological text book, *Principles of Physical Geology,* was published in 1965 it had proved to be just as popular as his first edition had been when that was published in 1944. The 1965 edition of "Holmes" had sufficient sales to allow it to be reprinted in 1966, 1969, 1970 and 1972.

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1 *Runcorn (1969), p 121.*

2 *See also the chapter by Hugh Owen.*

3 *Wood (1979).*

4 *Wood (1985), p 208*

5 *Wood (1985), p v.*

By the mid-1970s the publishers had decided some ideas presented in the book were not acceptable, particularly the chapter about Earth expansion. After Holmes's death his wife Doris took on the task of editing and updating the book, so in 1978 a third edition was published. In Doris L. Holmes preface to the third edition she was able to note that when,

> "In 1944, when the first edition of this book was published, it concluded with a chapter on Continental Drift. At that time this was very daring. Apart from masters of drift, like A. L. du Toit, who had proved its geological reality, even the few geologists who were prepared to discuss Continental Drift in the evening were inclined to dismiss it as too fantastic in the sober light of morning. Physicists, moreover, found it unacceptable.
>
> By the time the second edition was published in 1965, Continental Drift was a confirmed reality. From remnant magnetism in rocks, geophysicists had determined the positions of the poles for past periods, and proved that the continents have moved both relative to the poles and to one another since the Cretaceous. This then formed the highlight of the second edition together with such evidence as then existed—the migration of volcanic islands for example—that the ocean floors are moving away from the mid-oceanic ridges.
>
> During the following years geophysical discoveries continued to gain impetus, and there were many exciting and even fantastic revelations; movement of the ocean floors was firmly established from palaeomagnetic evidence, and their varying rates of movement determined. The culminating triumph was the evolution of the hypothesis of Plate Tectonics, which indeed might now be described as a theory, because it explains and correlates so many major features of the Earth."[1]

With her acknowledgement that the theory of Plate Tectonics was now considered to be the "culminating triumph" of geology we might well begin to wonder where this would leave the theory of Earth expansion within this updated edition. Would she continue with her husband's "very daring" advocacy of Earth expansion?

In practice she presented the evidence for expansion in a less demonstrative manner. The schematic illustration to indicate the effects of expansion of the Earth's interior, copied from Hilgenberg's original concept, was still there but the accompanying text had changed. Whereas Arthur Holmes had said, "we must seriously

[1] *Holmes D., Holmes A. (1979).*

consider the possibility that the Earth's interior is expanding" when he referred to this figure, Doris Holmes now said, "some geologists, notably Carey (1958), think … that the sialic crust has been pulled apart as a result of gradual expansion of the Earth's crust" when referring to the same figure. After introducing the possibility of expansion this chapter then continued with discussions of how a convection cell might also explain the evidence of new ocean basins forming. Arthur Holmes's original chapter on "The Expanding Earth" had been deleted.

The general impression that Earth expansion was an old idea that had now been supplanted by the better idea of Plate Tectonics is how virtually every text book began describing the development of the science.

The first Earth Expansion Symposium

In 1981, between 11 - 14 February, about 130 Earth scientists attended a meeting at Sydney University to discuss Earth expansion. Carey had organised the symposium with the help of the Earth Resources Foundation of the University and financial help from Australian and international mining and oil companies and the Australian Academy of Science.

Anyone attending the meeting would have been impressed by the participants Carey had persuaded to attend. Many were internationally known as leaders in the geological field. The formal opening speech was intended to be made by Sir Mark Oliphant, an Australian physicist and humanitarian who played an important role in the first experimental demonstration of nuclear fusion. Unfortunately he was unable to attend the opening due to a flight delay. Instead, his speech was read aloud so the participants could hear how he thought "the impressive list of contributors to the discussions makes it clear that there are believers outside the Tasmanian Apple Isle". Scanning the full list of attendees most people would have to agree. Besides the internationally known names there were professional geologists employed by companies, or academics in a specific geological discipline. The papers from the meeting were later published in the book, *The Expanding Earth: A Symposium*[1].

This first meeting would prove to be the first of many held all over the world discussing the mysteries of Earth expansion. Most were never reported by the science press but this didn't stop increasing numbers of researchers reading about the radical new concepts.

[1] *Carey (1983).*

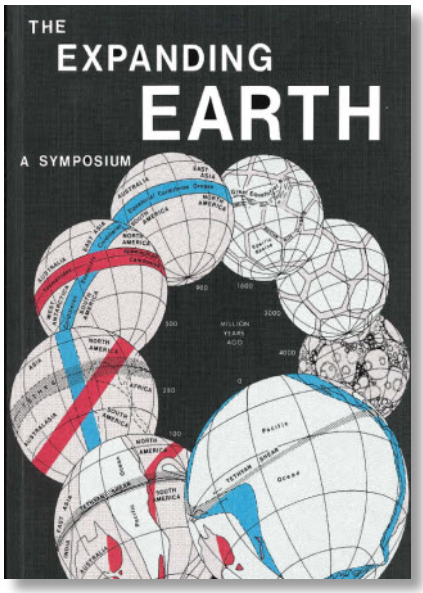

Fig 5. The cover and list of participants of "The Expanding Earth: A Symposium" from the book published to accompany the symposium. This was the first expanding Earth scientific meeting held to specifically discuss Earth expansion. Over the coming decades it would be followed by similar scientific meetings in various countries across the world including Russia, Italy, Poland, Greece and Germany.

PARTICIPANTS

AHMAD, Fakhruddin, *Jammu-Kashmir*
ALLEN, R.L., *Saltmat Mining*
ANDREJEWSKIS, A.J., *Ampol Exploration Ltd*
ARCHBOLD, N.W., *Melbourne University*
ARNOLD, G., *Geopeko, Sydney*
AUBREY, W.C., *Technical and Field Surveys Pty Ltd*
BAILEY, D.K., *Reading University, England*
BAINBRIDGE, A.M., *AI Sabiny Consultants*
BARNELL, A.J., *Ampol Exploration Ltd*
BESTON, N., *University of Newcastle*
BESLEY, R.E., *Union Oil Development Corporation*
BEVIS, Michael, *Cornell University*
BIESER, L.M., *Monash University*
BINNS, R.A., *CSIRO*
BLINOV, V.B., *Kiev, USSR*
BORSHOFF, J., *Cronomi Australia Pty Ltd*
BOUNDY, S., *Offshore Oil NL*
BOURKE, D.J., *Comalco Ltd*
BRADSHAW, J., *University of New South Wales*
BROWNE, A., *Geopeko*
BRUNSCHWEILER, R.O., *Consultant, Canberra*
BULL, P.F., *Amax Iron Ore Corporation*
BURRETT, Clive F., *University of Tasmania*
CAREY, S. Warren, *University of Tasmania*
CARMODY, J., *Ampol Exploration Ltd*
CECIONI, Giovanni O., *University of Chile, Santiago*
CHALLINGER, A., *BP Australia Ltd*
ĆIRIĆ, Branislav, *Geological Institut, Belgrade*
COCQUIO, G., *Minatome Australia Pty Ltd*
COTTON, R.J., *CRA Exploration Pty Ltd*
CRAWFORD, A.R., *University of Canterbury, New Zealand*
CROOK, Keith A.W., *Australian National University*
DACHILLE, Frank, *Pennsylvania State Univ., U.S.A.*
DAVIDSON, G., *Australian National University*
DAVIES, H., *Monash University*
DAVIDSON, John K., *Hobart, Tasmania*
DEE, C., *University of New South Wales*
DEGELING, P., *Geological Survey of New South Wales*
DIESSEL, C.F.K., *University of Newcastle*
DOOLEY, John C., *Bureau of Mineral Resources*
DRIVER, R.C., *Amax Iron Ore Corporation*
ELLISTON, John N., *Peko-Wallsend Ltd*
EMBLETON, Brian J., *CSIRO*
FETTERS, R.T., *Esso Australia Ltd*
FISHER, N.I., *CSIRO*
FOUNTAIN, R.J., *Amax Iron Ore Corporation*
GASKIN, Arthur J., *CSIRO*
GEORGEES, C., *Gold Copper Exploration*
GESTER, P.W., *Western Australian Petroleum Pty Ltd*
GLIKSON, Andrew Y., *Bureau of Mineral Resources*
GOLEBY, B., *Layton Geophysical International*
GORAI, Masao, *Tokyo*
GRAHAM, J.M., *Pennzoil of Australia*
GROVER, Helen Dee, *Vienna*
GUY, R.W., *Kingston, Jamaica.*
HANSEN, L., *Macquarie University*
HARRINGTON, H.J., *Bureau of Mineral Resources*
HERBERT, C., *Offshore Oil NL*
HEWSON, R., *Melbourne University*
HILYARD, D., *South Australian Institute of Technology*
HUNT, P., *ABC - Science Unit*
ITURRALDE-VINENT, Manuel A., *Havana, Cuba*
JEFFRIES, F.S., *Esso Australia Ltd*
JOHNSTON, C.R., *Bureau of Mineral Resources*
JONES, M., *Gold Fields Exploration*
KEMPTON, K., *Riverina College of Advanced Education*
KHAIANI, R., *Macquarie University*
KORSCH, R.J., *Armidale College of Advanced Education*
KREMP, Gerhard O.W., *University of Arizona, Tucson*
LAUGHTON, C.A., *BP Mining Development*
LAVERING, I.H., *Esso Australia Ltd*
LLOYD, A.R., *Asia Exploration Consultants, Singapore*
MAAZ, R., *Jena, East Germany*
MARSHALL, H., *New South Wales Institute of Technology*
MARSHALL, J.H., Jr., *Mobil Oil Corporation, New York*
MASON, D.J., *University of Newcastle*
MASON, D.R., *University of Newcastle*
MAUGER, A., *CSIRO*
McPHEE, I., *Beach Petroleum*
MOELLE, Konrad H.R., *University of Newcastle*
MORTON, D., *Esso Australia Ltd*
MYERS, Lawrence St. Clair, *Cdr., US Navy*
NEILANDS, J., *University of Newcastle*
NEIMAN, Vladimir B., *Moscow, USSR*
O'DRISCOLL, D.O., *Sydney*
O'DRISCOLL, E.S.T., *Western Mining Corporation*
OLLIER, C.D., *New England University*
OWEN, Hugh G., *British Museum, London*
PARKINSON, W.D., *University of Tasmania*
PAYNE, Barton, *Cornell University*
PFEUFER, Johannes, *Auerbach, West Germany*
PHILIP, Graeme M., *University of Sydney*
PLUMB, K.A., *Bureau of Mineral Resources*
RALSER, S., *Australian National University*
RAMBERG, Hans, *Uppsala University, Sweden*
RAY, M.
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RICHARDSON, R.L., *Peko-Wallsend Ltd*
RICKARD, M.J., *Australian National University*
ROGERS, M.C., *Geopeko*
ROYLE, D.J., *Amax Iron Ore Corporation*
RUNCORN, S. Keith, *University of Newcastle-on-Tyne*
RUTLAND, R.W.R., *Bureau of Mineral Resources*
SCHEINER, Irwin, *Geological Survey of N.S.W.*
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SMITH, Peter, *The Open University, London*
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STANMORE, P.J., *Esso Australia Ltd*
STEWART, A.D., *Reading University, U.K.*
STEWART, A.J.A., *Amax Iron Ore Corporation*
STÖCKLIN, Jovan, *Zurich*
STUTCHBURY, R., *Macquarie University*
SUN, S., *CSIRO*
SUTHERLAND, F.L., *Australian Museum*
TAILLEUR, Irv L., *US Geological Survey*
TALOBRE, J.A., *Paris*
TANNER, William F., *Florida State Univ., Tallahassee*
TASSOS, Stavros T., *National Observatory, Athens*
TAYLOR, S. Ross, *Australian National University*
TERMIER, Henri, *Paris*
TERMIER, Geneviève, *Paris*
THORBURN, H., *CSIRO*
THOMPSON, B.R., *Geological Survey of Victoria*
TRYON, Edward P., *Hunter College, New York*
UNFRED, D.N.
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VALSARDIEU, C., *Minatome Australia Pty Ltd*
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WARD, D.F.
WEZEL, Forese-Carlo, *Urbino, Italy*
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WILLIAMS, N., *Carpentaria Exploration*
WILLIAMS, R.E.
WILLIAMS, Brian, *Geopeko, Sydney*
WILTSHIRE, R.G., *South Australian Inst. of Technology*
WOODALL, Roy, *Western Mining Corporation Ltd*
WRIGHT, Kim, *Geopeko, Sydney*
YOUNG, Cynthia, *Esso Australia Ltd*
YOUNG, R.W., *University of Wollongong*
ZILKOWSKI, V., *Esso Australia Ltd*

Carey's second book – Theories of the Earth and Universe

By the mid-1980s Carey had written several scientific papers as well as his first book about expansion in 1976 with seemingly minimal engagement by the scientific establishment.

During a visit to science conferences in Italy it was suggested that a book aimed at the average reader might make more of an impression and the general outline of a new book began to form in his mind. Carey decided that his "armchair philosophy of an aging scientist did not warrant a formal bibliography" but noted that his previous book had 820 references for anyone who needed them.

The new book, *Theories of the Earth and Universe: History of Dogma in the Earth Science*[1], partly a history of both Carey and of science in general, started by tracing the evolution of beliefs about the Earth and Universe. New insights in geology had time and again had to fight for acceptance against entrenched scientific dogma. Once he had shown that history illustrates that the current popular view is often wrong he then started to discuss expansion. Carey highlighted the essential weaknesses in the plate tectonic theory showing that notions inherited from old discredited theories continued to infect much popular conventional geology. He then went on to explain the well-developed alternative theory of an expanding Earth. He didn't hide away from any of the attacks on the theory or its current disrepute in the English-speaking scientific community but explained at length its basis by highlighting the geological evidence. He showed how expansion explains many geological processes such as: mountain building, the evolution of the ocean floor and continental movements.

In the final section, he showed how planetary expansion seemed to be linked to the expansion of the universe. The logical consequence of the creation of the universe from nothing is an endless timeless cosmos that grows by adding mass and energy in equilibrium. This cosmological final section explores the very basis of time and space itself and is the null universe. It is a concept that is used for the instantaneous creation of the universe in the big bang model but was stretched over an immensity of time to explain continuous mass creation in Carey's model.

Carey included comprehensive details of the development of the theory from his last book with further evidence presented by a number of authors at the 1981 symposium held at the University of Sydney. He explained how many people in different countries had fitted all the continents together on globes nearly half the size of the

[1] *Carey (1988).*

current Earth. He detailed his visit to Klaus Vogel in 1979 when he handled Vogel's "globe in globe" reconstruction. Dr Kenneth Perry's computer reconstruction produced similar results but was made by programming a computer to move the continents radially outwards from their positions in Pangaea. This book is perhaps the easiest for a layman to gain an understanding of Earth expansion.

Earth, Universe, Cosmos

Carey's final book on the Expanding Earth, *Earth, Universe, Cosmos*[1], was published in 1996 by his old University of Tasmania to celebrate the fiftieth anniversary of the Geology Department. Readers with long memories will have recognised the graphic of the cover. It was the same one that had been used for the papers from the 1981 symposium, *The Expanding Earth*. The new book was dedicated to his students and updated the latest evidence indicating expansion. It was revised with a second edition[2] in 2000.

In 2002 Sam Carey died at a Hobart private hospital after several months of poor health. A memorial gathering was held in the Earth Science building at the University of Tasmania on Sunday 16 June 2002. About 80 of his former students and colleagues assembled to listen to talks about his life and works. An unusually intense earthquake was felt at 1.15 am on the same day as the memorial gathering, the aftershocks being recorded on a large seismograph in the front hall of the entrance to the Geology Department. Some of his friends noted that "his spirit is still with us" and the Earth might well be expanding.[3]

The hidden scientists uncovering the mysteries of Earth expansion

By the beginning of the 21st century it might have been easy for Plate Tectonic supporters to imagine that the Earth expansion idea had finally been put to rest after its long struggle to be heard and understood. The expanding Earth theory itself had been almost completely purged from most modern textbooks and its supporters were rarely mentioned even in history books.

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[1] *Carey (1996).*

[2] *Carey (2000).*

[3] *Scalera & Jacob (2003), p 92 – 93.*

Two widely read geological history books are typical examples of this obliteration: *In The Rejection of Continental Drift Theory and Method in American Earth Science*[1], written by the science historian Naomi Oreskes in 1998, neither Carey nor King even make it into the main text of the book. In 2002 the same historian and Homer Le Grand edited another book, *Plate Tectonics: An Insider's History of The Modem Theory of the Earth*[2], with chapters from some of the key individuals in the development of Plate Tectonics. In his chapter, *My Conversion to Plate Tectonics*[3], Xavier Le Pichon described how he regretted "the oblivion into which Warren Carey and Bruce Heezen have fallen"[4], confirming their almost total removal from science history. They had become part of the hidden history of science.

One of the most surprising aspects of the adoption of Plate Tectonics is how science as a whole failed to learn the lessons of history; in the second half of the 20th century science seemed to rebel against the very idea that the consensus view of science might be wrong. It was almost as though everyone had forgotten what we learned in the first half of the 20th century: some of what we currently believe may well be wrong and we should constantly seek to check our beliefs to see if there is a better description of the world. In the words of Carey, "disbelieve if you can" the popular theories you have been taught. Constantly check what you believe to see if there are better explanations. Only by constantly checking theories in this way can they be challenged. But in the second half of the 20th century science became more focused on one geological theory than ever before. Rather than adopting the role of scientists who used the concept of "multiple working hypotheses" science became fixated on one theory to the exclusion of all others. Plate Tectonics became the ruling theory that all geologists must adhere to without any murmur of dissent.

The policies that would make it easier for such dogmatic adherence to one theory were already being put in place by the 1960s. On 17 January 1961, President Dwight D. Eisenhower delivered his farewell address to the nation. In the speech President Eisenhower famously described the significant changes taking place in science. The technological revolution had been largely responsible for many sweeping changes during recent decades and research had become central. But by the 1960s research was starting to become more controlled by government departments.

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1 *Oreskes (1989).*

2 *Oreskes (2002).*

3 *Le Pichon (2002).*

4 *Oreskes (2002), p 222.*

> "Today the solitary inventor, tinkering in his shop, has been overshadowed by task forces of scientists, in laboratories and testing fields. In the same fashion, the free university, historically the fountainhead of free ideas and scientific discovery, has experienced a revolution in the conduct of research, partly because of the huge cost involved, a government contract becomes virtually a substitute for intellectual curiosity. For every old blackboard there are now hundreds of new electronic computers. The prospect of domination of the nation's scholars by federal employment, project allocations and the power of money is ever present and is gravely to be regarded."[1]

For centuries various authorities had tried to eliminate freedom of thought with religion and politics. Now the threat of revolutionary thoughts could be constrained by reducing funding to unapproved research. The additional linking of funding to the number of publications in approved scientific publications effectively handed control to the few chosen scientific elite who "peer reviewed" the research.

The more radical thinkers had their articles rejected since it didn't conform to the consensus view that the scientific authorities considered acceptable. Historically this claim of consensus has always been the first refuge of the authorities in science. In practice consensus is irrelevant to a true scientist. Only reproducible results are necessary. The great scientists who rewrote our understanding of nature were great precisely because they went against the unthinking consensus view.

For students, expansionists became classic examples of what might happen to any scientist who dared to challenge the consensus view. Their work went largely unreported or even ridiculed by science writers. Books were dismissed for not conforming to the popular concepts. Ideas were ignored. They had seemingly been forgotten.

Yet the theory of Earth expansion was to be slowly revived. Previously, expansionists had simply explored the concept in obscure science journals and organised their own conferences. However, over the next few years, with the powerful new technologies available in the 21st century, these old articles started to become visible to everyone at the click of a button. It was no longer possible to argue that Carey was a lone maverick because the evidence showed he wasn't alone. Expansionists may have been forced to publish their theories in obscure journals but now the internet allowed these articles to become easily visible to anyone who looked.

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[1] *Eisenhower (1961).*

Even some of the supporters of expansion were amazed at just how many papers had been published by numerous scientists around the world. Giancarlo Scalera undertook a comprehensive survey of all the expansionist papers up to 2002 and was surprised to find so many scientific papers hidden away in obscure publications:

> "… it is really an unexpected result that the number of published papers increased steadily in the years of the last century, with clear inflections due to the 2nd World War and a stagnant plateau precisely in the years of the birth of Plate Tectonics in the sixties and seventies. After this period of time the expansionists' papers were accepted for publications in Journals or Acta of peripheral importance, in proceedings of specific meetings, in monographies or in collective books resulting from 'call for papers'.
>
> I am personally convinced that if a paper is of influential importance for a scientific field, it will never be hidden or lost, whatever the quality and authority of the publisher may be. It will certainly arrive in the hands of people able to appreciate its novelty, even if not printed on glossy paper. Thanks to courageous editors in Australia, U.S.A., the United Kingdom, Greece, Italy, the Netherlands, Russian Federation, Japan, India, etc., it has been possible to hear the voices of the geoscience heretics. I do not believe that the database here produced is complete, I only hope it will become more and more complete in the course of the next few years with the help of all the modern protagonists of the expansion adventure."[1]

Soon it seemed that a host of new people were asking the same questions that had been asked half a century ago but this time the answer was very different. The old dismissal that "nobody believes that" was found to be obviously false with a quick search on the internet. This time it was possible to find many science papers discussing the concept. This time the question of Earth expansion raised its head and demanded a proper answer. This time the evidence that the Earth had been expanding refused to stay down. It slowly raised itself off the floor, flexed its muscles once again, and began to show it wasn't finished just yet.

In the following chapters we are now ready to meet the hidden scientists who have been uncovering the mysteries of Earth expansion. Their stories are all similar yet remarkably different. Most tell of rejection by the scientific authorities who regularly tried to prevent publication of the evidence. But it has always been the same for scientific revolutions and true scientists have always overcome these

[1] *Scalera (2003).*

obstacles. The concepts they have been exploring are so revolutionary that the mind does seem "to grow giddy" with the implications, just as John Playfair found when he tried to grasp the concept of an immensely old Earth. These are the hidden scientists still trying to prove that Earth expansion is true.

References

Afshordi, N. Mann, Robert, B. and Pourhasan, R. (2014). The Black Hole at the Beginning of the Time. Scientific American.311 (2) 38-43.

Ager, D.V. (1986). Migrating fossils, moving plates and an expanding Earth. Modern Geology, 10:377-390.

Ahmad, F. (1960). Glaciations and Gondwanaland. Geol. Surv. India. Rec. 86, 637-674.

Ahmad, F. (1990). The bearing of paleontological evidence on the origin of the Himalayas. In: A. Barto-Kyriakidis (Ed). Critical aspects of the Plate Tectonics theory. Theophrastus Publication, Greece. 1, 129-142.

Aitchinson, J. C. and 4 others. (2007). Shoshonites in southern Tibet record Late Jurassic rifting of a Tethyan intra-oceanic island arc. Jour. Geology. 115, 197-213.

Alfvén, H. (1942). On the cosmogony of the solar system. Stockholms Observatoriums Annaler, 14, 2–1.

Alfvén, H. (1954). On the origin of the solar system. Oxford University Press, New York.

Alfvén, Hannes (1984). Cosmology: Myth or Science? For the Golden Jubilee of the Indian Academy of Sciences, representing a culture which has investigated cosmology for four millennia, edited in Jour. Astrophysics and Astronomy, No. 5, 79-98.

Alfvén, H. (1992) Cosmology: myth or science? IEEE transactions on plasma science, vol. 20, no. 6, pp. 590–600.

Alfvén, H. Arrhenius, G. (1972). Origin and evolution of the earth-moon system. The Moon, 5(1-2), 210–230.

Alfvén, H. Arrhenius, G. (1976). Evolution of the solar system. NASA. Document number NASA-SP-345.

Ali, J.R. and Aitchinson, J.C. (2005). Greater India. Earth Science Review, 72, 169-188.

Allaby, M. (2013). A Dictionary of Geology and Earth Sciences. ISBN-13: 978-0199653065.

Amirmardfar, R. (2012). Relationship Between Gravity and Bio-Evolution - The Increasing Gravity Theory. In Boschi, Cwojdzinski & Scalera - editors (2012). The Earth expansion evidence – A Challenge for Geology, Geophysics and Astronomy.

Anderson, D.L. Yu-shen zhang, Tanimoto T. (1992). Plume heads, continental lithospere, flood basalts and tomography. W: Storey B. Alabaster T. Pankhurst R.J. (eds.): Magmatism and the Causes of Continental Break-up. Geol. Soc. Special. Publ. 68: 99-124.

Anderson, S.F. et al. (1999). Mapping low density galactic: third helium Lyman-alpha forest. Astronomic . 117, 56-62. DOI: 10.1086/300698; e-print: astro-ph/9808105 | PDF.

Antoshkina, A. Königshof, P. (2008). Lower Devonian reef structures in Russia: An example from the Urals. Facies. Doi: 10.1007/s10347-008-0135-7.

Aretz, M. Webb, G.E. (2003). Western European and eastern Australian Mississippian shallow-water reefs: A comparison. In: Proceedings of the XVth International Congress on Carboniferous and Permian Stratigraphy, Utrecht, The Netherlands, 10-16 August, 2003 (Ed. T.E. Wong), Roy. Ned. Acad. Arts Sci. 433-442.

Armijo, R. (1984). Quaternary extension of the Tibet plateau: field observation and technical implication. International Symposium Geology Himalayas.2, 17 (abstract).

Arrhenius, G. De, B. R. & Alfvén, H. (1974). Origin of the ocean. In The Sea, volume vol. 5 (pp. 839–861). Wiley New York, NY.

Badham, J.P.N. (1982). Strike-slip orogens – an explanation for the Hercynides. J. Geol. Soc. London, 139, 493-504.

Barcelo, C. Liberati, S. Sonego, S. Visser, M. (2009). Black Stars, Not Holes. Scientific American 301 February 46-52.

Barnett, C.H. (1962). A suggested reconstruction of the land masses of the Earth as a complete crust. Nature, 195 (4840), 447-448.

Becker, G. (1910). Age of the Earth. The Smithsonian institution, Washington.

Beaudette, C.G. (2002). Excess Heat: Why Cold Fusion Research Prevailed. Oak Grove Press South Bristol, ME.

Beloussov, V.V. (1979). Why don't I accept Plate Tectonics? EOS, 207-211.

Berhe, S.M. (1999.) Ophiolites in Northeast and East Africa: implications for Proterozoic crustal growth. (London: Journal of the London Geological Society; V. 147; No. 1, 51-57.

Bird, P. (2003). An updated digital model of plate boundaries. Geochemistry. Geophysics. Geosystem. 52, doi 10.1029/2001 GC 000252.

Blackett, P.M.S., Bullard, E., Runcorn, S.K. (eds.) (1965). A Symposium on Continental Drift. The Royal Society, London, x +323 pp.

Blinov, V.F. (1973). On the hypothesis of Earth's expansion. (In Russian). FizikaZemli 1, 27-35.

Bogolepow (1930), Die Dehnung de Lithoshare, Zeit, dt, geol. Ges., 82: 206-228.

Boucot. J. and Gray, J. (1987). The Tethyan concept during the Paleozoic. In: K.G. McKenzie (Ed).Shallow Tethys 2. A. A. Balkema, Rotterdam, 31-50.

Bouilhol, P. Jagoutz, O. Hanchar, J. M. and Dudas, F.O. (2013). Dating the India-Eurasia collision through arc magmatic records. Earth Planet Science Letter. 366, 163-175.

Boschi, Cwojdzinski & Scalera - editors (2012). The Earth Expansion Evidence: A Challenge for Geology, Geophysics and Astronomy. Selected Contributions to the Interdisciplinary Workshop held in Erice, Sicily, Italy, 4-9 October 2011 at the Ettore Majorana Foundation and Centre For Scientific Culture.

Brezinski, D.K. Cecil, C.B. Skema, V.W. Stamm, R. (2008). Late Devonian glacial deposits from the eastern United States signal an end of the mid-Paleozoic warm period. Palaeogeogr. Palaeoclim. Palaeoecol. 268, 143-151.

Bridges, L.W. (2002). Our expanding Earth. The ultimate cause. Oran V. Siler Printing. Denver Colorado.

Brownlee, R. & Cox, A. (1961). Early solar evolution. Sky and Telescope, (pp. 252–256).

Brosske (1962). Wachst die Erde mit Naturkatastrophen? Die 'Expansions-Theorie' (Does the Earth grow with natural catastrophes? The expansion theory.). 'Sanus' L. Brosske, Abtlg. Verlag, Dusseldorf-Benroth 41.

Brunnschweiler, R.O. (1983). Evolution of Geotectonic Concepts in the Past Century. In: Carey, S.W. (ed.): Expanding Earth Symposium. Sydney 1981, University of Tasmania, 9-15.

Buchan, K.L. Ernst, R.E. (2004). Diabase dyke swarms and related units in Canada and adjacent regions. Geological Survey of Canada Map 2022A, scale 1:5,000,000, accompanying report 39 pp.

Bullard, E. (1975). The emergence of plate tectonics: a personal view. Annual Review of Earth and Planetary Sciences, 3(1), 1-31.

Bullard, E.B. Everett, J.E. and Smith, A.G. (1965). The fit of the continents around the Atlantic. Philosophical Transaction of the Royal Society of London, A258, 41-51.

Burrett, C., Berry, R. (2000). Proterozoic Australia—Western United States (AUSWUS) fit between Laurentia and Australia, Geology 28, 103-106.

Carey, S.W. (1955). Wegener's South America–Africa Assembly, Fit or Misfit? Geological Magazine, 92(3), 196-200. doi:10.1017/S0016756800063548.

Carey, S.W. (1958). The tectonic approach to continental drift. In: Carey S. Warren (Ed). Continental Drift – A Symposium University of Tasmania, Hobart 177-355. Reprinted 1959.

Carey, S.W. (1961). Palaeomagnetic evidence relevant to a change in the Earth's radius (a reply to Cox & Doell). Nature, 190 (4770), 36-36.

Carey, S.W. (1976). The Expanding Earth. Developments in Geotectonics, 10, Elsevier, Amsterdam.

Carey, S.W. (1978). A philosophy of the Earth and Universe. Papers and Proceedings of the Royal Society of Tasmania, 112, 5-19.

Carey, S.W. (Editor) (1983). The Expanding Earth. A Symposium (Ed. S.W. Carey), University of Tasmania.

Carey, S.W. (1983). Tethys and her forebears. In: The Expanding Earth. A Symposium (Ed. S.W. Carey), University of Tasmania, 169-187.

Carey, S.W. (1988). Theories of the Earth and Universe: A History of Dogma in the Earth Sciences. Stanford University Press, Stanford, California, xviii+413 pp. ISBN 08047 1364 2.

Carey, S.W. (1996). Earth, Universe, Cosmos. University of Tasmania, Hobart, pp. 204.

Carey, S.W. (2000). Earth, Universe, Cosmos. 2nd Edition. University of Tasmania, Hobart.

Cataldi, G. & D., Straser, V. (2016). Solar activity correlated to the M7.0 Japan earthquake occurred. At New Concepts in Global Tectonics Journal, V. 4, No. 2, p. 79-85.

CGMW & UNESCO (1990). Geological Map of the World. Commission for the Geological Map of the World, Paris.

Chatterjee, S., Hotton III, N. (Editors) (1992). New Concepts in Global Tectonics. Texas Tech University Press. ix+ 449 pp.

Chatterjee, S., Scotese, C.R. (2010). The wandering Indian plate and its changing Biogeography during the Late Cretaceous-Early Tertiary period. In: S. Bandyopadhyay (Ed). New Aspects of Mesozoic Biogeography. Springer-Verlag, Germany, 105-126.

Chudinov, J.W. (1998) Global Eduction Tectonics of the Expanding Earth. VSP. Utrecht, the Netherlands.

Chatterjee, S., Bajpai, S. (2016). India's northward drift from Gondwana to Asia during the Late Cretaceous-Eocene. Proc. Indian National Science Academy, 82, 479-487.

Chatterjee, S., Goswami, A. Scotese, C.R. (2013). The longest voyage: Tectonic, magmatic and paleoclimatic evolution of the Indian plate during its northward fright from Gondwana to Asia. Gondwana Research, 23,238-267.

Choi, D.R. (2010). The January 2010 Haiti Seismic Disaster Viewed from the Perspective of the Energy Transmigration Concept and Block Tectonics. NCGT Newletter, 54,. 36-54.

Choi, D.R. Maslov, L. (2010). Global seismic synchronicity. NCGT Newletter, 55, 66-74.

Choi, D.S. Showman, A.P. Brown, R.H. (2009). Cloud features and zonal wind measurements of Saturn's atmosphere as observed by Cassini/VIMS. J. Geophys. Res. 114, E04007. Doi: 10.1029/2008JE003254.

Ciechanowicz, S., Koziar, J. (1994). Possible relation between Earth expansion and dark matter. In: F. Selleri, M. Barone (eds.), Proceedings of the International Conference "Frontiers of Fundamental Physics" (Olympia, Greece, 27–30 September, 1993). Plenum Press, New York and London, pp. 321–326.

Close, F. (2004). Particle Physics, a very short introduction. (Oxford: Oxford University Press. 160. ISBN 0-19 280434-0.

Colbert, E.H. (1973). Continental drift and the distributions of fossil reptiles. In: D.H. Tarling and S.K. Runcorn (Eds). Implications of continental drift to the Earth Sciences. Academic Press, 393-412.

Colbert, E.H. (1984). Mesozoic reptiles: India and Gondwanaland. Indian Journal Science, 11, 25-37.

Colpron, M., Nelson, J.L. (2009). A Palaeozoic Northwest Passage: incursion of Caledonian, Baltican and Siberian terranes into eastern Panthalassa, and the early evolution of the North American Cordillera. Geol. Soc. London, Spec. Publ. 318/1, 273-307. Doi: 10.1144/SP318.10.

Condie, K.C. (1997). Plate tectonics and crustal evolution. Fourth Edition, (Oxford: Butterworth-Heinneman, An Imprint of Elsevier Science Linacre House, Jordan Hill, Oxford OX2 BDP 200 and Wheeler Road, Burlington, MA, USA. 282.

Copper, P. (2002). Reef development at the Frasnian/Famennian mass extinction boundary. Palaeogeogr. Palaeoclimat. Palaeoecol. 181, 27-65.

Copper, P. Scotese, C.R. (2003). Megareefs in Middle Devonian supergreenhouse climates. Geol. Soc. Am. Spec Paper 370, 209-230.

Cox, C.B. (1975). Distribution of Triassic tertapods families. In: D.H.Tarling and S. K. Runcorn (Eds). Implications of continental drift to the Earth Sciences. Academic Press, 369-371.

Crawford, A.R. (1979). Gondwanaland and the Pakistan Region. Pp. 103-110 in Geodynamics of Pakistan, Ed. A. Farah and K.A. De Jong. Geo1ogical Survey of Pakistan, Quetta.

Creer, K.M. (1965). An expanding Earth? Nature, London 205, 539-544.

Cwojdziński, S. (1995) - Recenzja: R.Dadlez, W.Jaroszewski. Tektonika. Wyd. Nauk. PWN. Prz. Geol. 43, 3: 255 - 258. /Review of the book R.Dadlez, W.Jaroszewski. Tektonics. Sci Publ.PWN/.

Cwojdziński, S. (2001) Czy mo?liwa jest dyskusja naukowa w geotektonice. Przeg. Geol. 49, 10/1: 856 – 857 / Is the discussion in geotectonics possible ? Geol. Rev. 49. 10/1: 856-857.

Cwojdziński, S. (2003). The Tectonic Structure of the Continental Lithosphere Considered in the Light of the Expanding Earth Theory - A Proposal of a New Interpretation of Deep Seismic Data. Polish Geol. Inst. Spec. Papers, 9, 1-80.

Cwojdziński, S. (2004). Mantle plumes and dynamics of the Earth interior - towards a new model. Prz. Geol. /Geol. Review 52.8/2:817 - 826.

Cwojdziński, S. (2012). Geological Evolution of the Sudety Mts. (Central Europe) on the Expanding Globe. In: The Earth Expansion Evidence, A challenge for geology, geophysics and astronomy. Selected Contribution to the Workshop, held in Erice, Sicily, Italy (4-9 October 2011). 263-273. Post-conference publication edited by GiacarloScalera (editor in chief), EnzoBoschi, and Stefan Cwojdziński. Rome, 492.

Cwojdziński, S. (2016). History of a discussion: selected aspects of the Earth expansion v. plate tectonics theories. Geological Society, London, Special Publications, 442, SP442-24.

Cwojdziński, S., Koziar, J. (1995) Konferencja mi?dzynarodowa - Zagadnienia ekspanduj?cej Ziemi. Wroclaw-Sosnówka, 14-17.11.1994. Prz.Geol. 43, 4: 349 - 351.

Czechowski, L. & Leliwa-Kopystynski, J. (2013). Remarks on the Iapetus‘ bulge and ridge. Earth Planets Space, 65, 929-934. Doi: 10.5047/eps.2012.12.008.

Daly, R.A. (1917). Metamorphism and its phases. Geol. Soc. Am. Bull. 28, 375-418.

Davydov, V.I. (2016). Biotic paleothermometry constrains on Arctic plates reconstructions: Carboniferous and Permian (Zhokhov Island, De-Longa Group Islands, New Siberian Archipelago. Tectonics, 35, 2158-2170. Doi: 10.1002/2016TC004249.

Dearnley, R. (1965). Orogenic fold-belts, convection and expansion of the Earth. Nature, 206 (4991), 1284-1290.

De Celles, P.G. Kapp, P. Gehrels, G. Ding, L. 2014. Paleocene-Eocene foreland basin evolution in the Himalaya of southern Tibet and Nepal: Implications for the age of initial India-Asia collision. Tectonics, 33, 824-849.

De Hilster, D. (2008). The Growing Earth. p. 24. At: <www.dehister.com/docs/TheGrowingEarth.ppt>, 77.

De Lury, J.S. (1931). The auto-traction hypothesis of crustal dynamics and mechanics. Science (No. 1900), 73, 590.

De Lury, J.S. (1941). Correlation of schistosity and tectonic theory. Am. J. Sci. 239, 57-73.

Dewey, J.F. (2015). A harbinger of plate tectonics: a commentary on Bullard, Everett and Smith (1965) ‘The fit of the continents around the Atlantic’. Phil. Trans. R. Soc. A, 373(2039), 20140227.

Dewey, F., Bird, J.M. (1970). Plate Tectonics and geosynclines: Tectonophysics, 10, 624-638.

Dewey, J.F. Shackleton, R.M. Chang C. Sun Yin. (1988). The tectonic evolution of the Tibetan plateau: Phil. Trans. Royal Soc. London, 379-413.

Dickins, J.M. (1994). The nature of the oceans or Gondwanaland, fact and fiction. In: Gondwana Nine. A. A. Balkema, Netherland, 387-396.

Dietz, R.S. (1961). Continent and Ocean Basin Evolutionby Spreading of the Sea-Floor. Nature, London 190, 854-857.

Dietz, R.S. Holden, J.C. (1970). Reconstruction of Pangea: break-up and dispersion of continents. Permian to Recent.J.Geophys.Res. 75: 4,939-4,956.

Dilek, Y. and Robinson, P.T. (2003). Ofiolites in Earth History: Geological Society of London Special Publication 218 edited by Dilek, Y.& Robinson, P. T. 723 p.

Dilek, Y. Shallo, M. and H. Furnes. (2005). Rift-drift, seafloor spreading and subduction tectonics of Albanian ophiolites. International Geology Review V. 47. (New York: Taylor & Francis Group. 147-176.

Dimitriev, L.V. Vinogradov, A.P. and Udentsev, G.B. (1971). Petrology of ultrabasic rocks from rift zones of The Mid-Indian Ocean Ridge. Philosophical Transactions of the Royal Society of London. Series A Mathematical and Physical Sciences, V. 268, No. 1192. A discussion on Petrology of igneous and Metamorfic rocks from the Oceanic Flore. (London: The Royal Society,). 403-408.

Ding, L., Maksatbek, S,, Cai, F.L., Wang, H.Q., Song, P.P., Ji, W.Q., Zhang, L.Y., Mohammad, Q., Upendra, B. (2017). Processes of initial collision and suturing between India and Asia. China Earth Sciences, 60, 635-657.

Doglioni, C., Green, D.H., Mongelli, F. (2005). On the shallow origin of hotspots and the westward drift of the lithosphere. Geol. Soc. Am. Spec Paper 388, 735-749. Doi: 10.1130/2005.2388(42).

Doglioni, C., Carminati, E., Cuffaro, M., Scrocca, D. (2007). Subduction kinematics and dynamic constraints, Earth-Science Reviews 83, 125–175.

Doglioni, C., Carminati, E., Crespi, M., Cuffaro, M., Penati, M., Riguzzi, F. (2015). Tectonically asymmetric Earth: From net rotation to polarized westward drift of the lithosphere. Geosci. Frontiers, 6, 401-418.

Dorschner, J. (1986). Planeten – Geschwister der Erde? Urania Verlag,Leipzig, 128p.

Dumoulin, J.A., Harris, A.G., Gagiev, M., Bradley, D.C., Repetski, J.E. (2002). Lithostratigraphic, conodont, and other faunal links between lower Paleozoic strata in northern and central Alaska and northeastern Russia. Geol. Soc. Am. Spec. Paper 360, 291-312.

Drayson, A. (1859). The Earth we inhabit, its past, present, and probable future.

du Toit, A.L. (1937) Our Wandering Continents: An Hypothesis of Continental Drifting, Oliver & Boyd, London, UK.

Dziewoñski, A.M., Anderson, D.I. (1984). Seismic tomography of the Earth's interior. American Scientist. 72: 483-494.

Egyed, L., (1956). Determination of changes in the dimensions of the Earth from palaeogeographical data. Nature, 178, n.4532, 534-534.

Egyed, L., (1957). A new dynamic conception of the internal constitution of the Earth. Geol. Rundsch. B. 46, p. 101–121.

Eichler, J.B. (2011). A New Mechanism for Matter Increase Within the Earth. Nexus, April-May, 43-48; 82.

Eichler, J.B. (2015). Rhetoric and paradigm change in science: Three case studies. Master's thesis, University of Arkansas at Little Rock.

Eichler, J.B. (In press). An Infinite Universe.

Eisbacher, G.H. (1983). Devonian-Mississippian sinistral transcurrent faulting along the cratonic margin of western North America – A hypothesis. Geology, 11, 7-10.

Eisenhower, D. (1961). President Dwight Eisenhower Farewell Address. https://www.c-span.org/video/?15026-1/president-dwight-eisenhower-farewell-address.

Elbeze, A.C. (2013). On the existence of another source of heat production for the earth and planets, and its connection with gravitomagnetism. Published online: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3825064/ p.18

Ellis, M. Watkinson, A.J. (1987). Orogen-parallel extension and oblique tectonics: the relation between stretching lieations and relative plate motions. Geology, 15, 1022-1026

Elliston, J. (2003). Professor S.W. Carey's struggle with conservatism. In Scalera, G and Jacob, K-H. (Editors) 2003. Why Expanding Earth? A book in honour of Ott. Christoph Hilgenberg. INGV publisher Roma 97-114. (a reprint from Newsletters. The Australian Geologist, 125).

England, P. Houseman, G. Sonder, L. (1985). Length scales for continental deformation in convergent, divergent, and strike-slip environments: analytical and approximate solutions for a thin viscous sheet model. J. Geophys. Res. 90 (No. B5), 3551-3557

England, P. Jackson, J. (1989). Active deformation of the continents. Earth Planet. Sci. Ann. Rev. 17, 197-226.

Erickson, F.P. (2008). Absolute space, absolute time and absolute motion. 2678. Publisher: Xlibris, ISBN: 978-1599261171.

Erickson, W.C. (1980). Orgonomic Geophysics: The Earth as an Orgonotic System. Unpublished but posted online at Erickson (2001).

Erickson, W.C. (1982). Necessary Giants: Gravity and the Evolution of Dinosaurs. Unpublished.

Erickson, W.C. (1985). Rogue Scientist from Down Under. Unpublished but posted online at Erickson (2001).

Erickson, W.C. (1988). Ever Since Wegener: A Brief History of the Expanding Earth Hypothesis. Unpublished but posted online at Erickson (2001).

Erickson, W.C. (1989). Bipedal Hopping and the Origin of Dinosaurs. Unpublished but posted online at Erickson (2001).

Erickson, W.C. (1990). On the Origin of Dinosaurs and Mammals. Unpublished but posted online at Erickson (2001).

Erickson, W.C. (2001). Bill Erickson's Earth Science Web Page. https://www.frontier-knowledge.com/earth

Ernst, W.G. (1971). Metamorphic zonations on presumably subducted lithospheric plates from Japan, California and the Alps. Contrib. Min. Petr. 34, 43-59.

Ernst, W.G. (1973). Blueschist metamorphism and P-T regimes in active subduction zones. Tectonophys. 17,255-272.

Ernst, W.G. (1993). Metamorphism of Franciscan tectonostratigraphic assemblage, Pacheco Pass area, east-central Diablo Range,, California Coast Ranges. Geol. Soc. Am. Bull. 105, 618-636.

Eskola, P. (1939). Die metamorphen Gesteine. In: Die Entstehung der Gesteine. Ein Lehrbuch der Petrogenese. (Ed. C.W. Correns), Julius Springer, Berlin (Reprint 1970), 263-407.

Evans, J.V. (1958). Insect distribution and continental drift. 134-141. In Carey (1958).

Ewing, M., Heezen, B.C. (1956). Some problems of Antarctic submarine geology. Geophys. Monogr, 1(462), 75-81.

Fairbridge, R.W., (1964). Thoughts about an expanding globe. In: Subramanion, A.P. and Balakrishna, S. (eds.): Advancing Frontiers in Geology and Geophysics. Osmania University Press, Hyderabad, 59-88.

Farley, K.A. Neroda, E. (1998). Noble Gases in the Earth's Mantle. Annual Review of Earth and Planetary Sciences.Vol. 26: 189-218 From: http://www.annualreviews.org/doi/abs/10.1146/annurev.earth.26.1.189

Felt, H. (2012). Soundings: The story of the remarkable woman who mapped the ocean floor. ISBN: 978-0-8050-9215-8.

Fernandez, M.S. Khosla, A. (2015). Para taxonomic review of the Upper Cretaceous dinosaurs eggshell belonging to the family Megaloolithidae from India and Argentina. Historical Biology, 27, 158-180.

Ferry, J. (1992). Regional metamorphism of the Waits River Formation, Eastern Vermont: delineation of a new type of giant metamorphic hydrothermal system. J. Petr. 33, 45-94.

Fleck, L. (1981). Genesis and development of a scientific fact. University of Chicago Press.

Forsyth D., Uyeda, S.. (1975). On the Relative Importance of the Driving Forces of Plate Motion, Geophysical Journal of the Royal Astronomical Society 43, 163-200.

Fox, S.W., Dose, K. (1977). Molecular Evolution and the Origin of Life (Revised ed.). Marcel Dekker, New York, 370 pp.

Fox, S.W, Harada, K., Kendrick, J. (1959). Production of spherules from synthetic proteinoid and hot water: Science 129: 1221-1223.

Frankel, H. (2012). The Continental Drift Controversy. A Four Volume Set. Cambridge University Press.

Frisch, W. Meschede, M. (2005). Plattentektonik. Kontinentverschiebung und Gebirgsbildung.Wissenschaftliche Buchgesellschaft, Darmstadt, 196p.

Galilei, G. (1638). Two New Sciences. Holland.

Ganapathy, R. Keays, R. R. Laul, J. & Anders, E. (1970). Trace elements in Apollo 11 lunar rocks: Implications for meteorite influx and origin of moon. Geochimica et Cosmochimica Acta Supplement, vol. 1, p. 1117.

Ganapathy, R. & Anders, E. (1974). Bulk compositions of the moon and earth, estimated from meteorites. In Lunar and Planetary Science Conference Proceedings, vol. 5, pp. 1181–1206.

Gansser, A. (1973). Facts and theories on the Andes. J. Geol. Soc. London, 129, 93-131.

Gansser, (1991). Facts and theories on the Himalayas. Eclogie. Geol. Helv. 84, 33-59.

Gapais, D. Le Corre, C. (1980). Is the Hercynian belt of Brittany a major shear zone? Nature, 288 (No. 5791), 574-576.

Garzanti, E. Hu, X. (2014). Latest Cretaceous Himalayan tectonics: Obduction, collision or Deccan related uplift? Gondwana research, doi: 10.1016/ j.gr.2014.1003.1010.

Gibbons, A. S. and 4 others. (2015). A tectonic model reconciling evidence for the collisions between India, Eurasia and intra-oceanic arcs of the central-eastern Tethys.Gondwana research, doi: 10.1016/ j.gr.2015.1001.1001.

Gilliland, W.N. (1964). Extension of the theory of zonal rotation to explain global fracturing. Nature, 202, 1276-1278

Gold, T. (1987). Power from the Earth. Dent, London. Pp. 208.

Gold, T. (1988). Das Jahrtausend des Methans. Die Energie der Zukunft – unerschöpflich, umweltfreundlich.Econ Verlag Düsseldorf, Wien, 256p

Gold, T. (1989). New ideas in science. J. Sci. Explor. 3/2, 103-112

Gong, E. Zhang, Y. Guan, C. Chen, X. (2012). The Carboniferous reefs in China. J. Palaeogeogr. 1, 27-42. Doi: 10.3724/SP.J.1261.2012.00004.

Goswami, A. and 4 others. (2013). A troodontid dinosaur from the latest Cretaceous of India. Nature Communications, 4, 1-5.

Glenn, W. (1982). The road to Jaramillo. Critical years of the revolution in Earth Science. Stanford University Press. 459 pp.

Greenfield, J. (1974). Wilhelm Reich vs. the U.S.A. W.W. Norton & Company, New York, 380 pp.

Gurnis, M. Hall, C. Lavier, L. (2004). Evolving force balance during incipient subduction. Geochemistry Geophysics Geosystem, 5, 1-31.

Gutenberg, B. (1951). Internal constitution of the Earth, volume 7. Dover Publications Inc.

Guy, R. (2005). The Mysterious Receding Seas. ISBN: 978-1413439922

Gurnis, M. Yang, T. Cannon, J. Turner, M. Williams, S. Flament, N. Müller, R.D. (2018). Global tectonic reconstructions with continuously deforming and evolving rigid plates. Computers & Geosciences, 116, 32-41. Doi: 10.1016/j.cageo.2018.04.007

Hall, C.E. and 6 others. (2003). Catastrophic initiation of subduction following forced convergence across fracture zones. Earth and Planetary Science Letters, 212, 15-30.

Hall, R. (1996). Reconstructing Cenozoic SE Asia. In: Tectonic Evolution of SE Asia (Eds. R. Hall, D.J. Blundell), Geol. Soc. London Spec. Publ. 106, 153-184

Hall, R. (2002). Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions, model and animations. J. Asian Earth Sci. 20, 353-431.

Hall, R. (2012). Late Jurassic-Cenozoic reconstructions of the Indonesian region and the Indian Ocean. Tectonophys. 570-571, 1-41. Doi: 10.1016/j.tecto.2012.04.021.

Hallam, A. (1983). Great Geological Controversies. Oxford University Press.

Hambry, M. J. & Harland, W. B. eds. (1981). Earth's Pre-Pleistocene glacialrecord. Cambridge: Cambridge University Press, London.

Hanmer, S. Vigneresse, J.L. (1981). Mis en place de diapirs syntectoniques dans la chaîne hercynienne: Exemple des massifs leucogranitiques de Locronan et de Pontivy (Bretagne Centrale). Bull. Soc. Geol. France, S7-XXII/2, 193-202. Doi: 10.2113/gssgfbull.S7-XXII.2.193

Hamilton, W.B. (1979). Tectonics of the Indonesian Region, US Geological Survey Professional Paper 1078. United States Government Printing Office, Washington, DC, ix + 345 pp.

Hamilton, W.B. (2011). Plate Tectonics began in neoproterozoic time, and plumes from deep mantle have never operated. Lithos, vol. 123, no. 1-4, pp. 1–20.

Hamilton, W.B. (2019). Toward a myth-free geodynamic history of Earth and its neighbors, Earth-Science Reviews 198, 102905.

Harrison, C.G.A. (2016). The present day number of tectonic plates. Earth, Planet and Space, 68, doi: 10.1186/s40623-016-0400-x.

Heezen, B.C., (1959a). Geologie sous-marine et deplacements des continents. Colloques Internationaux du Centre National de la Recherche Scientificue, N° LXXXIII, Paris, 295-302.

Heezen, B.C., (1959b). Paleomagnetism, continental displacements, and the origin of submarine topography. International Oceanographic Congress. Reprints of Abstracts: Am. Assoc. Advance. Sci.

Heezen, B.C. (1960). The rift in the ocean floor. Scientific America, 203, 98-110.

Heezen, B.C., Ewing, M. (1961). The mid-oceanic ridge and its extension through the Arctic Basin: Geology of the Arctic.

Heezen, B.C., Tharp, M. (1965). Tectonic fabric of the Atlantic and Indian Oceans and continental drift. Philosophical transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences, 258(1088), 90-106.

Heezen, B.C., Tharp, M. (1966). Physiography of the Indian Ocean.

Heirtzler, J.R. (1977). A Minority View in Geophysics, Science 196, 778.

Hess, H.H. (1962). History of Ocean Basins. In Engel, A.E.J. James, H. L. and Leonard, B.F. (Editors). Petrologic Studies. A volume in honour of A.F.B. Boddington. Geological Society of America 599-620.

Herndon, J.M. (2005). Whole-Earth decompression dynamics. Curr. Sci. 89/11, 1937-1941.

Herndon, J.M. (2011). Geodynamic basis of heat transport in the Earth. Curr. Sci. 101/11, 1440-1450.

Hilgenberg, H. (2003). The life and work of Ott Christoph Hilgenberg: as seen by his daughter, Helge Hilgenberg. In Scalera, G., Jacob, K-H., (Editors) (2003). Why Expanding Earth? A book in honour of Ott Christoph Hilgenberg. INGV publisher Rome. 465 pp with extensive bibliography.

Hilgenberg, O.C. (1933). Vom Wachsenden Erdball. (On Growing Earth) Berlin Giessmann und Bartsch 56 pp.

Hilgenberg, O.C. (1933/2003). The Formation and development of Earth: contraction or expansion. In: Why Expanding Earth? (Eds) Scalera, G. Jacob, K. Proceedings of the Lautenthal Colloquium held on May 26, 2001 in honor of Ott Christoph Hilgenberg. Rome (2003).

Hilgenberg, O.C. (1960?/2003). The formation and development of the Earth: contraction or expansion? (Fragments from the last unpublished manuscript). In Giancarlo Scalera, and Karl-Heinz Jacob (eds): Why Expanding Earth? A book in honour of O.C. Hilgenberg. Proceedings of the Lautenthal Colloquium, held on May 26, 2001. INGV publisher Rome, 53-64.

Hilgenberg, O.C. (1962). Rock magnetism and the Earth's palaeopoles. Geofisica pura e applicata, 53(1), 52-54.

Hilgenberg, O.C. (1966). Die Paläogeographie der expandierenden Erde vom Karbon bis zum Tertiär nach paläomagnetischen Messungen. Geologische Rundschau, 55(3), 878-924.

Hilgenberg, O.C. (1967/2015). Why Earth expansion? Rheologic evidence of the Earth's expansion. https://www.dinox.org/publications/Hilgenberg1967.pdf

Hilgenberg, O.C. (1974). Geotektonik, neuartig gesehen. Geotektonische Forschungen (Geotectonic Research), 45, Schweizerbartsche Verlagsbuchhandlung, Stuttgart, 194p.

Hodgin, R.C. (2008). NASA snaps photo of remote planet. Information by (November 13, 2008). At: http://www.tgdaily.com/trendwatch-features/40192-nasa-snaps-photo-of-remote-planet-25-light-years-away-using-visible-light-

Holland, H.D. (1984). The Chemical Evolution of the Atmosphere and Oceans. Princeton, N.J.: Princeton University Press.

Hole, M. J. & Natland, J. H. (2019). Magmatism in the North Atlantic Igneous Province; mantle temperatures, rifting and geodynamics. Earth Science Reviews, [Earth_2018_391]. https://doi.org/10.1016/j.earscirev.2019.02.011

Holmes, A. (1913). The Age of the Earth.

Holmes, A. (1931). Radioactivity and Earth Movements. Transactions of the Geological Society of Glasgow, 18, 559-606, 1931, https://doi.org/10.1144/transglas.18.3.559.

Holmes, A. (1944). Principles of Physical Geology. Thomas Nelson, xii+532, reprinted 1945, revised and expanded 1965.

Holmes, A. (1965). Principles of Physical Geology. Second edition. Nelson, London, pp.1288.

Holmes, D., Holmes, A. (1978). Principles of Physical Geology. Third edition.

Hooft, G. (2007). The conceptual basis of quantum field theory. In: The Oxford Handbook of Philosophy and physics. (Ed. Robert Batterman, p. 661-729).

Hoshino M. (1998). The Expanding Earth: Evidence, Causes and Effects. Tokai University Press, 295 pp.

Hu, X. and 5 others. (2016). The timing of India-Asia collision onset – Fact, theories, controversies. Earth Science Review, 160, 264-299.

Huismans, R.S., Beaumont C. (2014) Rifted continental margins: The case for depth-dependent extension, Earth and Planetary Science Letters 407 148-162.

Hurrell, S.W. (1994). Dinosaurs and the Expanding Earth. One-off Publishing, 222 pp. ISBN 0952260301

Hurrell, S.W. (2011). Dinosaurs and the expanding Earth: One explanation for the gigantic sizes of some pre-historic life. U.K.: One off, 3rd edition. ISBN 9780952 26037 0

Hurrell, S.W. (2011). Ancient life's gravity and its implications for the expanding Earth. (Extended abstract). In Extended Abstracts of the 37th Interdisciplinary Workshop of International School Geophysics. Sicily. "The Earth Expansion Evidence: A challenge for Geology, Geophysics and Astronomy" Volume: Pre-conference book - Extended abstracts. DOI: 10.13140/2.1.1522.4643.

Hurrell, S.W. (2012). Ancient Life's Gravity and its Implications for the Expanding Earth. In The Earth expansion evidence – A Challenge for Geology, Geophysics and Astronomy - Selected Contributions to the Interdisciplinary Workshop of the 37th International School of Geophysics. Aracne Editrice, Roma. https://www.earth-prints.org/handle/2122/8838

Hurrell, S.W. (2014). A New Method to Calculate Palaeogravity Using Fossil Feathers. NCGT Journal, v. 2, no. 3, September, 2014. p 29-34.

Hurrell, S.W. (2017). Early speculations about Earth expansion by Alfred Wilks Drayson (1827-1901) and William Thorp (1804-1860). https://dinox.org/hurrell2017

Hurrell, S.W. (2018). A palaeogravity calculation based on weight and mass estimates of Giraffatitan (=Brachiosaurus) brancai. https://dinox.org/hurrell2018a

Hurrell, S.W. (2019a). Palaeogravity calculations based on weight and mass estimates of four Tyrannosaurus rex specimens. https://dinox.org/hurrell2019a

Hurrell, S.W. (2019b). A palaeogravity calculation based on weight and mass estimates of Acrocanthosaurus atokensis. http://dinox.org/hurrell2019b

Hurrell, S.W. (2019c). Palaeogravity calculations based on weight and mass estimates of two Coelophysis bauri specimens. http://dinox.org/hurrell2019c

Hurrell, S.W. (2019d). A Palaeogravity calculation based on weight and mass estimates of Gigantoraptor erlianensis. http://dinox.org/hurrell2019d

Hurrell, S.W. (2019e). A Palaeogravity calculation based on weight and mass estimates of Ankylosaurus magniventris. http://dinox.org/hurrell2019e

Hurrell, S.W. (2019f). A Palaeogravity calculation based on weight and mass estimates of Euoplocephalus tutus. http://dinox.org/hurrell2019f

Hurrell, S.W. (2019g). A Palaeogravity calculation based on weight and mass estimates of Megalosaurus bucklandii. http://dinox.org/hurrell2019g

Hurrell, S.W. (2019h). Palaeogravity calculations based on weight and mass estimates of Paraceratherium transouralicum. http://dinox.org/hurrell2019h.

Hutton, J. (1788). Theory of the Earth: or an investigation of the laws observable in the composition, dissolution, and restoration of land upon the globe. Royal Society of Edinburgh.

Hutton, J. (1795). Theory of the Earth. Volume I.

Hsü, K. (ed.), (1982). Mountain Building Processes. Academic Press, London, pp.263.

Ingersoll, R.V. (1988). Tectonics of sedimentary basins. Geol. Soc. Am. Bull. 100, 1704-1719.

Irving, E. (1977). Drift of major continental blocks since the Devonian. Nature, 270, 304-309.

Ishikawa, A., Pearson, D.G., Dale, C.W. (2011). Ancient Os isotope signatures from the Ontong Java Plateau lithosphere: tracing lithospheric accretion history, Earth and Planetary Science Letters 301 159-170.

Jackson, H.R. and Gunnarson K. (1990). Reconstructions of the Arctic: Mesozoic to Present. Tectonophysics 172, 303-322.

Jacob, K.-H. (1974). Deutung der Genese von Fluoritlagerstätten anhand ihrer Spurenelemente, insbesondere an fraktionierten seltenen Erden (Interpretation of the genesis of fluorine deposits

based on trace elements, with emphasis on fractionated rare earths), TU Berlin, 99 pp.

Jacob, K.-H. (2010). Über Selbstorganisation und ihre Bedeutung für die Geologie. (About self-organization and its importance in geology). Zeitschrift für Geologische Wissenschaften (ZGW), Berlin, 38, 295-310, 6 plates.

Jacob, K.-H., Dietrich, S., Krug, H.-J. (1994). Self-organization in mineral fabrics. In: Fractals and Dynamic Systems in Geosciences (Ed.: J.H. Kruhl), Springer, 259-268.

Jacob, K.-H., Dietrich, S. (2012). Electric Field Forces and Self-Organization. From Common Concepts to New Insights. In: The Earth Expansion Evidence – A Challenge for Geology, Geophysics and Astronomy. Selected Contributions to the Interdisciplinary Workshop of the 37th International School of Geophysics EMFCSC, Erice (4-9 October, 2011) (Eds.: G. Scalera, E. Boschi, S. Cwojdzinski), 407-419.

Jagoutz, O., Royden, L., Holt, A.F., Becker, T.W. (2015). Anomalously fast convergence of India and Eurasia by double subduction. Nature Geosciences Letters. 8, 475-478.

Japsen, P. Bidstrup, T. Lidmar-Bergström, K. (2002). Neogene uplift and erosion of southern Scandinavia induced by the rise of the South Swedish Dome. In A.G. Doré, J.A. Cartwright, M.S. Stoker, J.P. Turner & N. White (eds.): Exhumation of the North Atlantic margin: timing, mechanisms and implications for petroleum exploration, 299–314. Geological Society, London, Special Publication 162.

Jardetzky, W.S. (1929). La rotation zonale de la planète et les dérives continentales. Acad. Roy. Serbe, Glas. Belgrade, 134, 150-157

Jardetzky, W. (1954). The principal characteristics of the formation of the Earth's crust. Science, 119 (No. 3090), 361-365

Jiang, S. He, M. Yue, W. Qi, B. & Liu, J. (2007). Observation of ^{3}He and ^{3}H in the volcanic crater lakes: possible evidence for natural nuclear fusion in deep Earth. In 8th International Workshop on Anomalies in Hydrogen/Deuterium Loaded Metals, Sicily, Italy: Citeseer.

Ji'an S. Mingguo Z. Lüqiao Z. Daming L. (2004). Identification of Five Stages of Dike Swarms in the Shanxi-Hebei-Inner Mongolia Border Area and Its Tectonic Implications. Acta Geologica Sinica – English Edition, 78, 320-330.

Johnson, A. (2019). The Earth… but not as We Know It.

Johnson, B.D. Powell, C. McA. and Veevers. J.J. (1980). Early spreading history of the Indian Ocean between India and Australia. Earth and Planetary Science Letters . 47, 131-143.

Johnson, M.R.W. (2002). Shortening budgets and the role of continental subduction during the India-Asia collision. Earth Science Review. 59, 101-123.

Jones, S. & Ellsworth, J. (2003). Geo-fusion and cold nucleosynthesis in tenth international conference on cold fusion. Cambridge, MA: LENR-CANR. org.

Jordan, P. (1966). Die Expansion der Erde. Vieweg, Braunschweig, 182p.

Jordan, P. (1973). The expanding earth. The Physicist's Conception of Nature.

Kahle, C.F. (1974). Plate Tectonics—Assessments and Reassessments. American Association of Petroleum Geologists. SBN-10: 0891812997. ISBN (electronic): 9781629812182.

Karna Lidmar-Bergström, Mats Olvmo & Johan M. Bonow (2017). The South Swedish Dome: a key structure for identification of peneplains and conclusions on Phanerozoic tectonics of an ancient shield, GFF, DOI: 10.1080/11035897.2017.1364293.

Kasting, J. F. & Howard, M. T. (2006). Atmospheric composition and climate on the early earth. Philosophical Transactions of the Royal Society B: Biological Sciences, 361(1474), 1733–1742.

Ketner, K.B. (2012). An alternative hypothesis for the mid- Paleozoic Antler orogeny in Nevada. USGS, Prof. Paper 1790, 11p.

Khan, Z.A. and Tewari, R.C. (2016). The concept of Gondwanaland and Pangaea- A appraisal: Journal of Applied Geology and Geophysics, v.4, p.44-56. doi: 10.9790/0990-0403024456.

Khan, Z.A. and Tewari, R.C. (2017). Problems in accepting Plate Tectonics and subduction as a mechanism of Himalayan evolution. Jour. Applied Geology and Geophysics. 5, 81-100.

Khan, Z.A. and Tewari, R.C. (2018). Indus-Yarlung Tsangpo Suture zone concept- A second opinion. Jour. Tethys, 5, 218-239.

Kiessling, W. Flügel, E. Golonka, J. (1999). Paleoreef maps: Evaluation of a comprehensive database on Phanerozoic reefs. AAPG Bulletin, 83/10, 1552-1587.

King, L.C. (1983). Wandering Continents and Spreading Sea Floors on an Expanding Earth. Wiley, Chichester, pp. 232.

Keindl, J. (1940) Dehnt sich die Erde aus? Eine geologische Studie. (Is the Earth expanding? A geological study.), Herold-Verlag Dr. Franz Wetzel & Co., Munchen-Sollin, pp.50.

Klootwijk, C.T. (1986). Greater India's margin: Paleomagnetic evidence for large-scale continental subduction, In: K.G. McKenzie (Ed).Shallow Tethys 2. A. A. Balkema, Rotterdam, 529.

Kokus, M. (2004). Alternate theory of gravity and geology in seismic prediction. In New Concepts in Global Tectonics; Urbino Workshop 29-31 Aug. Italy.

Kort, L. (1949). Das Wachen der Earth und die Wanderung der Kontinente. Buchdruckerei, Hannover, pp. 53.

Koziar, J. (1980). Ekspansja den oceanicznych I jej zwiazek z hipotaza ekspansji Ziemi. Sprawozdania Wroclawskiego Towarzystwa Naukowego, 35, 13-19. [Expansion of the ocean floors and its connection with the hypothesis of the expanding Earth. Reports of the Wroclaw Scientific Society, vol. 35B. Ossolineum, Wroclaw, pp. 13–19.]

Koziar, J. (1985). Rozwój oceanów jako przejaw ekspansji Ziemi. Geologia nr 8. Uniwersytet Slaski, Katowice, s. 109–114. [Development of the oceans as a manifestation of Earth's expansion. Geology no. 8. The Silesian University, Katowice, pp. 109–114.]

Koziar, J. (1991). Prace nad problemami ekspansji Ziemi w oœrodku wroclawskim. Acta Universitatis Wratislaviensis, nr 1375, s. 110–156. [Research on the Expanding Earth in the Wrocław scientific community. Acta Universitatis Wratislaviensis, no. 1375, pp. 110–156.]

Koziar, J. (1991). Nowa rekonstrukcja Gondwany na ekspanduj¹cej Ziemi, na tle rekonstrukcji dotychczasowych. Acta Universitatis Wratislaviensis, nr 1375, s. 357–396. [A new reconstruction of Gondwana on the expanding Earth. Acta Universitatis Wratislaviensis, no. 1375, pp. 357–396.]

Koziar, J. (1993). Rozwój Pacyfiku i jego znaczenie dla współczesnej geotektoniki. W: J. Skoczylas (red.), Streszczenia referatów, tom II. Polskie Towarzystwo Geologiczne – Oddział w Poznaniu i Instytut Geologii Uniwersytetu im. Adama Mickiewicza w Poznaniu, Poznañ, s. 45–56. [Development of the Pacific and its significance to the contemporary geotectonics. (The expanding Pacific). In: J. Skoczylas (ed). Lecture summaries. vol. II. The Polish Geological Society – Poznañ Branch and the Institute of Geology of the Adam Mickiewicz University in Poznañ, Poznañ, pp. 45–56.]

Koziar, J. (1994). Principles of plate movements on the expanding Earth. In: Frontiers of Fundamental Physics. Eds. M.Barone & F.Selleri. Plenum Press. New York & London: 301 - 307.

Koziar, J. (2003). Tensional development of active continental margins. In: K. H. Jacob (ed.), Materials of the International Conference „Erdexpansion – eine Theorie auf dem Prüfstand" (24–25 May, 2003, Ostbayern Schloss Theuern (Germany). Technische Universität, Berlin, pp. 27–35.

Koziar, J. (2005). Tensyjny rozwój orogenów sródladowych. Czêsc I, Mechanizm. W: J. Skoczylas (red.), Streszczenia referatów, tom XIV. Polskie Towarzystwo Geologiczne – Oddział w Poznaniu i Instytut Geologii Uniwersytetuim. Adama Mickiewicza w Poznaniu, Poznañ, s. 131–156. [Tensional development of intracontinental fold belts. Part I, Mechanism. In: J. Skoczylas (ed.), Lecture summaries, vol. XIV. The Polish Geological Society – Poznañ Branch and the Institute of Geology of the Adam Mickiewicz University in Poznañ, Poznañ, pp. 131–156.]

Koziar, J. (2005). Tensyjny rozwój orogenów œródladowych. Czêsc II, Przykłady regionalne. W: J. Skoczylas (red.), Streszczenia referatów, tom XIV. Polskie Towarzystwo Geologiczne – Oddział w Poznaniu i Instytut Geologii Uniwersytetu im. Adama Mickiewicza w Poznaniu, Poznañ, s. 157–196. [Tensional development of intracontinental fold belts. Part II, Global examples. In: J. Skoczylas (ed.), Lecture summaries, vol. XIV. The Polish Geological Society – Poznañ Branch and the Institute of Geology of the Adam Mickiewicz University in Poznañ, Poznañ, pp. 157–196.]

Koziar, J. (2006). Terrany, czyli geologia w krainie duchów. W: J. Skoczylas (red.), Streszczenia referatów, tom XV. Polskie Towarzystwo Geologiczne – Oddział w Poznaniu i Instytut Geologii Uniwersytetu im. Adama Mickiewicza w Poznaniu, Poznañ, s. 47–98. [Terranes: or geology in a phantoms world. In: J. Skoczylas (ed.), Lecture summaries, vol. XV. The Polish Geological Society – Poznañ Branch and the Institute of Geology of the Adam Mickiewicz University in Poznañ, Poznañ, pp. 47–98.]

Koziar, J. (2007). Tensional origin of the inversion in the Polish Basin with reference to tensional development of the Bohemian Massif. Extended abstract. In: B. Kontny, V. Schenk (eds.), Abstracts of the 8th Czech – Polish Workshop „On Recent Geodynamics of the Sudety Mts. and Adjacent Areas" (Kłodzko, Poland, 29–31 March, 2007). Wrocław University of Environmental and Life Sciences, Wrocław, pp. 17–21.

Koziar, J. (2011). Shortening of the Length of Day (LOD) Caused by Big Tsunami Earthquakes on the Expanding Earth (extended abstract). In: S. Cwojdziñski, G. Scalera (eds.), Pre-Conference Extended Abstracts Book of the 37th Course of the International School of Geophysics. Interdisciplinary Workshop on "The Earth Expansion Evidence: A challenge for Geology, Geophysics and Astronomy."(Ettore Majorana Foundation and Centre for Scientific Culture, Erice, Sicily, 4–9 October, 2011). Istituto Nazionale di Geofisica e Vulcanologia, Rome, pp. 55–58.

Koziar, J. (2012). Expanding Earth and Space Geodesy. Society of Geologist Alumni of Wroclaw University. Wroclaw 2018.

Koziar, J. (2018). Falsification of the Eulerian motions of lithospheric plates. Circularity of the plate tectonics theory. LAP LAMBERT Academic Publishing.

Koziar, J. (2018). Geological proofs of significant expansion of the Earth and its broader scientific context. Association of Geologist Alumni of Wroclaw University, Wroclaw, PL. ISBN 978-83-950414-1-9.

Koziar, J., Jamrozik, L. (1985). Application of the tension–gravitational model of the tectogenesis to the Carpathian orogen reconstruction. In: Proceeding reports of the XIIIth Congress of the Carpatho – Balkan Geological Association (Cracow, Poland, 5–10 September, 1985), part I. Polish Geological Institute, Cracow, pp. 200

Koziar, J., Jamrozik, L. (1994). Tension–gravitational model of island arcs. In: F. Selleri, M. Barone (eds.), Proceedings of the International Conference "Frontiers of Fundamental Physics" (Olympia, Greece, 27–30 September, 1993). Plenum Press, New York and London, pp. 335–337.

Koziar, J., Muszyñski, A. (1980). Spostavki meždu ekstenzjonnoto rozvitije na Srediziemno i Èerno morje. Spisanje na Blgarskoto Geologièesko Družestva, god. XLI, kn. 3, s. 247–259. [Correlations of extensional development of the Mediterranean and the Black Sea. Review of the Bulgarian Geological Society, vol. 41, no. 3, pp. 247–259.]

Krause, D.W. and 4 others. (1997). Cosmopolitanism among Gondwanian Late Cretaceous mammals. Nature, 390, 178-208.

Krouss, L. (2014). A Beacon from the Big Bang. Scientific American 4, 311.59-67.

Krug, H.-J., Dietrich, S., Jacob, K.-H. (1994). The formation and fragmentation of periodic bands through precipitation and Ostwald ripening. In: Fractals and Dynamic Systems in Geosciences (Ed.: J.H. Kruhl), Springer, 269-289.

Kuhn, T. (1970). The structure of scientific revolutions. University of Chicago press, 2nd ed edition.

Kundt, W. (1998). The Gold effect: Odyssey of scientific research. arXiv:astro-ph/9810059v1, 54 S.

Larson R.L. Pitman W.C. (III), Golovchenko X. Cande S.C. Dewey J.F. Haxby W.F. & LaBrecque (mapcompilers) (1985). The Bedrock Geology of the World. Freeman & Co. New York.

Lay, T. Hernlund, J. Buffett, A.B. (2008). Core–mantle boundary heat flow. In Nature Geoscience, No. 1, p. 25-32.

Laya-Pereira, J.C. (2012). Permian carbonates in the Venezuelan Andes. Doctoral Thesis, Durham Univ. 330p.

Leclerc, G-L. (1751). Theory of the Earth.

Le Grand, H.E. (1988). Drifting Continents and Shifting Theories. Cambridge University Press.

Le Pichon, X. (1968). See-floor spreading and continental drift. J.Geophys.Res. 73, 12:3661 - 3697.

Le Pichon, X. (2001). My Conversion to Plate Tectonics. In Oreskes, N. (editor), Le Grand, H.E. (2001). Plate tectonics: An insider's history of the modern theory of the Earth. Westview Press.

Lerner, E. (1992). The Big Bang never happened. Vintage Books, New York.

Lewis, C. (2000). The Dating Game: One Man's Search for the Age of the Earth, Cambridge University Press, ISBN 0-521-89312-7

Leyton, M. Monroe, J. (2017). The Source for Up to Half of Earth's Internal Heat Is Unknown. Web: https://www.realclearscience.com/articles/2017/08/05/the_source_for_up_to_half_of_earths_internal_heat_is_unknown.html

Liang Rixuan, Bai Wanji. (1984). Genesis of ultramafic rocks in Yarlu-Zhangbo ophiolite belt. International Symposium Geology Himalaya, 1, 117-118 (Abstract).

Lindemann, B. (1927). Kettengebirge, Kontinentale Zerspaltung und Erdexpansion. Gustav Fischer Publishers, Jena. 186p.

Love, J.J. Thomas, J.N. (2013). Insignificant solar-terrestrial triggering of earthquakes. Geophysical Research Letters. Vol.40, is. 6:1165-1170.

Lovelock, J.E. (1979). Gaia: A new look at life on Earth. Oxford University Press, Oxford, 176 pp.

Low, F. S. Kristna, S. (1970). Narrow bond infrared photometry of alfatory. Nature: 3. 23. 13-22.

Lyell, C. (1830). Principles of Geology: being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation. Part I.

Managadze, G.G., Cherepin, V.T., Shkuratovm Y.G., Kolesnik, V.N., Chumikov, A.E. (2011). Simulating OH/H2O formation by solar wind at the lunar surface, Icarus 215, 449–451.

Mardfar - See Amirmardfar.

Makarenko G.F. (1983). Volcanic Seas on Earth and Moon. (In Russian), (Moscow, Izdatel's tvo Nedra.

Marvin, D. (2018). The Expanding Earth and the Implications on the Geophysics of Earth. 44p.

Marvin, J.H. (2003). The Nuclear Heart of the Earth. Interview at: http://www.spacedaily.com/news/earth-03k.html.

Marvin, J.H. (2014). Herdon's Earth and the Dark Side of Science; Perface at: http://nuclearplanet.com/Herdon's_Earth%20.html.

Molnar, P. Tapponnier, P. (1975). Cenozoic tectonics of Asia: effects of a continental collision: Science, 189, 419-426.

Manuel K. Oliver (2009). Earth's Heat Source, the Sun. At: Energy & Environment 20131-144. https://arxiv.org/ftp/arxiv/papers/0905/0905.0704.pdf.

Mareschal, J-C. et al. (2012). Geoneutrinos and the energy budget of the Earth. Journal of Geodynamics, Vol. 54, p. 43– 54.

Maxlow, J. (1995). Global Expansion Tectonics: The geological implications of an expanding Earth. Unpublished Master of Science thesis, Curtin University of Technology, Perth, Western Australia.

Maxlow, J. (2001). Quantification of an Archaean to Recent Earth Expansion Process Using Global Geological and Geophysical Data Sets. PhD thesis, Curtin University of Technology, Western Australia.

Maxlow, J. (2002). Quantification of an Archaean to recent Earth Expansion Process using Global Geological and Geophysical Data Sets. Unpublished PhD thesis, Curtin University of Technology, Perth, Western Australia.

Maxlow, J. (2003). Quantification of an Archaean to Recent Earth expansion process. In Scalera, G and Jacob, K-H. (Editors) 2003. Why Expanding Earth? A book in honour of Ott. Christoph Hilgenberg. INGV publisher Roma. 335-349.

Maxlow, J. (2005). Terra non firma Earth: Plate Tectonics is a myth. Terrella Press.

Maxlow, J. (2014). On the Origin of Continents and Oceans: A Paradigm Shift in Understanding. Perth, Western Australia: Terrella Press.

Maxlow, J. (2015). Expansion Tectonics: A Complimentary Download. Terrella Press, 114p.

Maxlow, J. (2018). Beyond Plate Tectonics: Unsettling settled science. Aracne Editrice, Roma. www.aracneeditrice.it

McCarthy, D. (2003). The trans-pacific zipper effect: disjunct sister taxa and matching geological outlines that link the pacific margins. Journal of Biogeography, 30(10), 1545–1561. https://doi.org/10.1046/j.1365-2699.2003.00929.x

McCarthy, D. (2011). Here be dragons: how the study of animal and plant distributions revolutionized our views of life and Earth. OUP Oxford.

McElhinny M.W. Lock J. (1996). IAGA paleomagnetic databases with Access. Surveys in Geophysics, 17, 575-591.

McKenzie, D.P. (1977). Plate Tectonics and Its Relationship to the Evolution of Ideas in the Geological Sciences, Daedalus Vol. 106 No. 3, 97-124.

Menard, H.W. (1986). The Ocean of Truth: A Personal History of Global Tectonics. Princeton University Press.

Meservey, R. (1969). Topological inconsistency of continental drift in the present-sized earth. Science.

Meyerhoff, A.A., Tanner, I., Morris A.E.L., Martin, B.D., Agocs, W.B., Meyerhoff, H.A. (1992). Surge tectonics: a new hypothesis of Earth dynamics. In: Chatterjee, S. and Hotton, N. (eds.): New Concepts in Global Tectonics. Texas Tech. University Press, Lubbock, 309-409.

Meyerhoff, A.A. (1995). Surge-tectonic evolution of southeastern Asia: A geohydro-dynamics approach. Jour. Southeast Asian Earth Sciences, 12, 143-247.

Meyerhoff, A.A., Boucot, A.J., Meyerhoff, H.D., Dickins, J.M. (1996). Phanerozoic faunal and floral realms of the Earth: The intercalary relations of the Malvinokaffric and Gondwana faunal realm with the Tethyan faunal realm. Mem Geological Society of America No. 189.

Miller, E.L. Kuznetsov, N. Soboleva, A. Udoratina, O. Grove, M.J. Gehrels, G. (2011). Baltica in the Cordillera? Geology, 39/8, 791-794. Doi: 10.1130/G31910.1.

Mizuno, T. (1998). Nuclear transmutation: the reality of cold fusion. Infinite Energy Press Concord.

Molnar, P. (2007). An examination of evidence used to infer late Cenozoic "Uplift" of mountain belts and other high terrain: What scientific question does such evidence pose? Journal of the Geological Society of India. 70, 395-410.

Moores, E.M. (1991). Southwest U.S.—East Antarctic (SWEAT) connection: A hypothesis. Geology 19, 425-428.

Moores, E.M. Kellogg, L.H. and Dilek, Y. (2000). Tethyan Ophiolites, mantle convection and tectonic historical contingency: A resolution of the ophiolite conundrum. GSA. Inc. Special Paper #349 in Ophiolites and Oceanic Crust: New Insight from the Field Studies and the Drilling Program, 349, 3-12.

Myers, L.S. (2004). Earth expanding rapidly by external accretion expansion. In Urbino Workshop 29-31 August.

Myers, L.S. (2008). A growing and expanding Earth is no longer questionable. (Washington, D.C.: American Geophysical Union, Spring Meeting,. 26a. Myers).

Myers, L.S. (2015). Gravity: The Source of Earth's Water. Page Publishing Inc. ISBN-13: 978-1682137116.

Najman, Y. and 9 others. (2010). Timing of India-Asia collision: geological, biostratigraphic and paleomagnetic constraints. Jour. Geophy. Research, 115, 1978-2012.

Neuendorf, K.K.E., Mehl Jr, J.P., Jackson, J.A. (Editors) (2011). Glossary of Geology (Fifth Edition), Revised, American Geosciences Institute, Alexandria, Virginia.

Neiman, V.B., 1962: Razsirjajuscajasja Zemlja (The expanding Earth). Gosudarstvennoje Izdatelstwo Geograficeskoj Literatury, Moskwa.

Nicolas, A. Bouchez, J.L. Blaise, J. Poirier, J.P. (1977). Geological aspects of deformation in continental shear zones. Tectonophys. 42, 55-73.

Nicolas, A. Poirier, J. P. (1976): Crystalline Plasticity and Solid State Flow in Metamorphic Rocks. J. Wiley & Sons, London, 444p.

Nicolis, G., Prigogine, I. (1987). Die Erforschung des Komplexen. Piper, München, Zürich, 384 pp.

Noel, D. (1986). Nut tree distributions and the expansion of the Earth. http:// wayback.archive-it.org/1941/20100524190351/http://www.wanatca.org.au/Q-Yearbook/Y11all.pdf

Noel, D. (1989). Nuteeriat: nut trees, the expanding Earth, Rottnest Island, and all that–. Published for the Planetary Development Group, Tree Crops Centre by Cornucopia Press. Reprint available from

Amazon, https://www.amazon.com/Nuteeriat-Expanding-Rottnest-Island-P-Book/dp/1982976624/

Noel, D. (2012). Inside The Earth -- The Heartfire Model. http://www.aoi.com.au/bcw/Heartfire/index.htm

Noel, D. (2013). Inside the Earth -- The Heartfire Model. http://www.aoi.com.au/bcw/Heartfire/index.htm

Noel, D. (2017a). EP302: The Earth-Expansion Model Part A --The Death of Plate Tectonics. http://www.aoi.com.au/EP/EP302.htm. [A revision of "Fixed-Earth and Expanding-Earth Theories -- Time for a Paradigm Shift?" <http://www.aoi.com.au/bcw/FixedorExpandingEarth.htm> 2004.]

Noel, D. (2017b). EP303: The Earth-Expansion Model Part B -- Answers to A Hundred Puzzles. http://www.aoi.com.au/EP/EP303.htm [A revision of "Fixed-Earth and Expanding-Earth Theories -- Time for a Paradigm Shift?" <http://www.aoi.com.au/bcw/FixedorExpandingEarth.htm> 2004.]

Noel, D. (2017c). XT807: The Concore Model of planet and star interiors. http://www.aoi.com.au/Extracts/XT807.htm [An extract from Inside "The Earth -- The Heartfire Model". ref. 9, 2012]

Norin, E. (1946). Geological expedition in Western Tibet: Report Sino-Swedish Expedition, Stockholm, 1-229.

Nutman, A.P. Clark R.L. Friend C.R.L. Bennett V.C. McGregor V.C. (2004). Dating of the Ameralik dyke swarms of the Nuuk district, southern West Greenland: mafic intrusion events starting from c. 3510 Ma. Journal of the Geological Society, 161, 421-430; DOI: 10.1144/0016-764903-043.

Ogrisseg, J. (2009). Dogmas may blinker mainstream scientific thinking. https://www.japantimes.co.jp/life/2009/11/22/life/dogmas-may-blinker-mainstream-scientific-thinking/

Ollier, C.D. (1969). 'Weathering', Oliver & Boyd, Edinburgh, 304.

Ollier, C.D. (1981). Tectonics and Landforms, Longman, Harlow, 324.

Ollier, C.D. (2002). The structure and origin of mountains: Pre-planation and post-planation gravity structures. in Dramis F. Farabollini P. Molin P. (Eds.) Large-scale vertical movements and related gravitational processes. In: Proc. International Workshop, Camerino-Roma 21-26 June 1999, Studi Geologici Camerti, Numero Speciale; pp.147- \155, Edimond,

Ollier, C.D. (2003). The origin of mountains on an expanding Earth, and other hypotheses. In Scalera,G. & Jaob, H. (eds) Why Expanding Earth. 129 – 160 . INGV Publisher, Rome.

Ollier, C.D. (2004). The evolution of mountains on passive continental margins. 59 – 88 In: Slaymaker, O. and Owens, P. (eds.): Mountain Geomorphology. Edward Arnold, London, Città di Castello (Italy).

Ollier, C.D. (2006). A plate tectonics failure: the geological cycle and conservation of continents and oceans. Annals of Geophysics, Supplement to Vol. 49, N. 1, Chapter 8, 427-436.

Ollier, C.D. (2007). Exceptional planets and moons, and theories of the expanding Earth. New Concepts in Global Tectonics, 45, 52-54.

Ollier, C.D. (2012a). Dykes, crustal extension and global tectonics. In Scalera, G. Boschi, E. and Cwojdzinski (eds.) The Earth Expansion Evidence – a challenge for Geology, Geophysics and Astronomy. Selected Contributions to the Interdisciplinary Workshop of the 37th International School of Geophysics EMFCSC, Erice (4-9 October 2011), 207 – 304.

Ollier, C.D. (2012b). Extension everywhere: rifts, continental margins and island arcs. In Scalera, G. Boschi, E. and Cwojdzinski (eds.) In The Earth Expansion Evidence–a challenge for Geology, Geophysics and Astronomy. Selected Contributions to the Interdisciplinary Workshop of the 37th International School of Geophysics EMFCSC, Erice (4-9 October 2011), 61 – 76.

Ollier, C.D., Koziar, J. (2007). Dlaczego cykle geologiczne tektoniki p³yt nie sprawdzaj¹ siê? Przegl¹d Geologiczny, tom 55, nr 5, s. 375–382. [Why the plate tectonics rock cycles do not work? Geological Review, vol. 55, no. 5, pp. 375–382.]

Ollier, C.D. Pain, C.F. (2000). The Origin of Mountains, Routledge, London.

Ollier, C.D. Pain C.F. (2019). Neotectonic mountain uplift and geomorphology. Geomorfologiya. 2019;(4):3-26. https://doi.org/10.31857/S0435-4281201943-26.

Öpik, E. (1971). Cratering and the moon's surface. In Advances in Astronomy and Astrophysics. Elsevier, vol. 8, pp. 107–337.

Oreskes, N. (1989). The Rejection of Continental Drift: Theory and Method in American Earth Science.

Oreskes, N. (editor), Le Grand, H.E. (2002). Plate tectonics: An insider's history of the modern theory of the Earth. Westview Press.

Orlando, T.M., Jones, B.M., Aleksandrov, A.B., Hibbits, C.A., Dyar, M.D. (2018). A Solar Wind Source of Water in the Polar Regions of the Moon? Lunar Polar Volatiles 2018 (LPI Contrib. No. 2087).

Orlenok, V. (2010). Global volcanism and oceanization of the Earth and planets. Kaliningrad: I.Kant State University of Russia Press, 167.

Ortoleva, P. (1984). Geochemical Self-Organization. Oxford Monogr.Geol. Geophys., 23, 411 pp.

Owen, H.G. (1976). Continental displacement and expansion of the Earth during the Mesozoic and Cenozoic. Philosophical Transactions of the Royal Society of London. A 281, 223-291.

Owen, H.G. (1983). Atlas of continental displacement 200 million years to the Present. Cambridge Earth Sciences Series. Cambridge University Press. i-x, 1-159, 76 maps.

Owen, H.G. (1984). The Earth Is Expanding and We Don't Know Why. In New Scientist, No. 22, Nov. 22, 1984. 27-

Owen, H.G. (1996). Boreal and Tethyan late Aptian to late Albian ammonite zonation and Palaeobiogeography. Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg. 77, 461-481.

Owen, H.G. (2012). Earth expansion - Some Mistakes, What Happened in the Palaeozoic and the Way Ahead. In Scalera G. Boschi, E. and Cwojdzinski, S Editors. The Earth Expansion Evidence – A challenge for Geology, Geophysics and Astronomy Erice, Sicily, 4-9 October 2012, 77-89.

Owen, L.A. (2004). Cenozoic evolution of global mountain systems. 132 – 152 In: Slaymaker, O. and Owens, P. (eds.): Mountain Geomorphology. Edward Arnold, London.

Patriat, F., Achache, J. (1984). The Indian-Eurasian collision. A synthesis of oceanic magnetic anomalies and the comparison with continental paleomagnetic studies. International Symposium Geology Himalayas, 2, 14 (abstract).

Peale, J.S. (1999). Origin and Evolution of the Natural Satelits. Annu. Rev. Astron. Astrophys. 37:533–602.

Peishing, Bao and Wang Xibin. (1984). The two suites of volcanic in the Yarlung-Zhangbo River ophiolite belt - a discussion on the emplacement mechanism of ophiolites. International Symposium Geology Himalaya 1, 103-105 (Abstract).

Pfeufer, J. (1981). Die Gebirgsbildungsprozesse als Folge der Expansion der Erde. Glückauf, Essen, 125 pp.

Pisarevsky, S. (2005). Global Paleomagnetic Database (GPMDB V 4.6). Tectonics Special Research Centre of the University of Western Australia Web site (http://www.tsrc.uwa.edu.au/).

Pitcher, W.S. Atherton, M.P. Cobbing, E.J. Beckinsale, R.D. (1985). Magmatism at a Plate Edge. Blackie, Halstead Press, Glasgow, 328p.

Playfair, J. (1802). Illustrations of the Huttonian Theory of the Earth.

Poirier, J.P. (1976). Crystalline Plasticity and Solid State Flow in Metamorphic Rocks. J. Wiley & Sons, London, 444p.

Popper, K.. (1963). Science as falsification. In The Growth of Scientific Knowledge (pp. 33–39). London: Routledge.

Prasad, G. R. Verma, O. Flynn, J.J. and Goswami, A. (2013). A late Cretaceous vertebrate fauna from the Cauvery basin, South India: Implications for Gondwanian paleogeography. Jour. Vertebrate Paleontology, 33, 1260-1268.

Pratt, D. (2000). Plate Tectonics: A paradigm under threat. Jour. Scientific Exploration. 14, 307-352.

Priestley, J. (1767). The History and Present State of Electricity. London.

Puchkov, V.N. (2009). The evolution of the Uralian orogen. (London: Geological Society, Special publication, V. 327, 2009), 161-195. DOI: 10.1144/SP327.9.

Rage, J.C. (2003). Relationships of the Malagasy fauna during the Late Cretaceous: Northern of southern routes? ActaPaleontologicaPolonica, 48, 661-662.

Rage, J.C. (2016). Gondwana, Tethys and terrestrial vertebrates during Mesozoic and Cenozoic. In: Gondwana and Tethys. M.G. Audrey-Charles and A. Hallam (Eds.).Geological Society of America Special publication 37, 255-273.

Raiverman, V. (1992). Trans-Asiatic lineaments and Himalayan orogeny, In: A. K. Sinha (Ed). Himalayan Orogen and global tectonics: Oxford & IBH. Publication, New Delhi, 121-156.

Raiverman, V. (2002). Foreland sedimentation in Himalayan tectonic regime: A relook at the Orogenic process: B.S. M. P.S. Publ, New Delhi, 1- 378.

Rattclife, H. (2017). A review of Anomalous Redshif Data. In: The Galileo of Polmar. Essay in memory of Alton Arp edited by Christofer C. Fulton and Martin Cocus.

Reading, H.G. (1980). Characteristics and recognition of strike-slip fault systems. In: Sedimentation in Oblique-Slip Mobile Zones (Eds. P.F. Balance, H.G. Reading), Internat. Assoc. Sedimentol. Spec. Publ. 4, 7-26.

Reich, W. (1945/1982). The Bioelectrical Investigation of Sexuality and Anxiety. Farrar, Straus and Giroux, New York, xi + 161 pp.

Reich, W. (1949/1951/1973). Ether, God and Devil/Cosmic Superimposition. Farrar, Straus and Giroux, New York, 308 pp.

Reston, T. (2007). Extension discrepancy at North Atlantic nonvolcanic rifted margins: Depth-dependent stretching or unrecognized faulting? Geology 35, 367-370.

Rickard, M.J. (1969) Relief of curvature on expansion - a possible mechanism of geosynclinal formation and orogenesis. Tectonophysics 8(2): 129 - 144.

Reitan, P.H. (1968a). Frictional heat during metamorphism: quantitative evaluation of concentration of heat generation in time. Lithos, 1, 151-163.

Reitan, P.H. (1968b). Frictional heat during metamorphism: quantitative evaluation of concentration of heat generation in space. Lithos, 1, 268-274.

Reitan, P.H. (1988). Global dynamics and the temperatures of metamorphism. Bull. Geol. Inst. Univ. Uppsala, N.S. 14, 21-24.

Rogers, (1985). Quote given in Carey (1988).

Romanowicz, B., Gung, Y. (2002). Superplumes from the Core-Mantle Boundary to the Lithosphere: Implications for Heat Flux." Science 96.5567. (Stanford, CA: Highwire Press, 2002).513-516. DOI: 10.1126/science.1069404.

Romans, B. (2008). Subduction Denialism, Part 1: The Backstory. https://clasticdetritus.com/2008/11/14/subduction-denialism-part-1-the-backstory/

Roques, M. (1941). Les schistes cristallins de la partie sud-ouest du Massif Central Français. Mém. Serv. Carte géol. France, 512p.

Rubin, V.C. (1988). Dark matter in the universe. Proceedings of the American Philosophical Society, vol. 132, no. 3, pp. 258–267.

Runcorn, S.K. (Ed.). (1962). Continental drift. Elsevier.

Runcorn, S.K. (Ed.). (1969). The Application of the Modern Physics to The Earth and Planetary Interiors. (N.A.T.O. Advanced Study Institute)

Rust, J. and 15 Others. (2010). Biogeographic and evolutionary implications of a diverse paleobiota in amber from the early Eocene of India. Proc. National Academy Science, 107, 18360-18365.

Sarwar, G. and Khalil, Y.S. (2017). The saga of India's drift and supra-subduction origin of the ophiolites on its northwestern margin, Pakistan.New Concepts in Global Tectonics Journal. 5, 27-47.

Scalera, G. (2003). Samuel Warren Carey. Commemorative memoir. In Scalera, G. and Jacob, K-H., (Editors) 2003. Why Expanding Earth? A book in honour of Ott Christoph Hilgenberg. Proceedings of the 3rd Lautenthaler Montanistisches Colloquium, Mining Industry Museum,

Lautenthal (Germany) May 26, 2001 (INGV Publication, Rome), 85-95.

Scalera G. (2003). The expanding Earth: a sound idea for the new millennium. In: G. Scalera and K.-H. Jacob (eds.): Why Expanding Earth? – A book in Honour of Ott Christoph Hilgenberg. Proceedings of the 3rd Lautenthaler Montanistisches Colloquium, Mining Industry Museum, Lautenthal (Germany) May 26, 2001 (INGV Publication, Rome), 181-232.

Scalera, G. (2003). Bibliographical sources for the expanding Earth. In: G. Scalera and K.-H. Jacob (eds.): Why Expanding Earth? – A book in Honour of Ott Christoph Hilgenberg. Proceedings of the 3rd Lautenthaler Montanistisches Colloquium, Mining Industry Museum, Lautenthal (Germany) May 26, 2001 (INGV Publication, Rome).

Scalera, G. (2006). The Mediterranean as a slowly nascent ocean. Annals of Geophysics, Supplement to V. 49, No. 1, 451-482.

Scalera, G. (2008). Great and old earthquakes against great and old paradigms – paradoxes, historical roots, alternative answers. Advances in Geosciences, 14, 41–57.

Scalera, G. (2009). Mantovani and his ideas on the expanding Earth, as revealed by his correspondence and manuscripts. Annals of Geophysics, 52(6), 615-648.

Scalera, G. (2011). South American volcanoes and great earthquakes. Article Cwojdziñski. Rome, (2012), 492.

Scalera, G. (2011). The Earth Expansion Evidence, A challenge for geology, geophysics and astronomy. Contribution to the Interdisciplinary Workshop, held in Erice, Sicily, Italy (4-9 October 2011). Post-conference publication edited by Giancarlo Scalera (editor in chief), EnzoBoschi, and Stefan Cwojdziñski. Rome (2012), 492.

Scalera, G. (2013). The vague volcano-seismic clock of the South American Pacific margin. Advances in Geosciences, 35, 89–103.

Scalera G., Braun, T. (2003). Ott. Christoph Hilgenberg in twentieth century Geophysics. In Scalera, G and Jacob, K-H., (Editors) 2003. Why Expanding Earth? A book in honour of Ott Christoph Hilgenberg. INGV publisher Roma. 25-41.

Scalera, G., Jacob, K-H., (Editors) (2003). Why Expanding Earth? A book in honour of Ott Christoph Hilgenberg. INGV publisher Rome. 465 pp with extensive bibliography.

Scalera, G. (editor in chief): Hilgenberg, O. C. (2003/1933/1939) Formation and development of the: contraction or expansion. In Giancarlo Scalera, and Karl-Heinz Jacob (eds): Why Expanding Earth?

Proceedings of the Lautenthal Colloquium, held on May 26, 2001 Honour off OttChistoph Hilgenberg. INGV, Rome 2003.

Scalera, G., Boschi, E. and Cwojdzinski (Editors) (2012). The Earth Expansion Evidence – A challenge for Geology, Geophysics and Astronomy. Selected Contributions to the Interdisciplinary Workshop of the 37th International School of Geophysics EMFCSC, Erice (4-9 October 2011), Aracne Editrice, Rome, 494pp.

Schaer, J.P. and Rogers, J. (1987). The Anatomy of Mountain Ranges. Princeton University Press, Princeton, N.J. pp.298.

Sharaf, M. (1983). Fury on Earth, A Biography of Wilhelm Reich. St. Martin's Press, New York, xiii + 550 pp.

Schirber, M. (2005). Core of a Supernova Goes Missing. At: http://www.space.com/1168-core-supernova-missing.html.

Scholz, C.H. (1980). Shear heating and the state of stress on faults. J.Geophys. Res. 85 (No. B11), 6174-6184

Scholz, C.H. Beavan, J. Hanks, T.C. (1979). Frictional metamorphism, argon depletion, and tectonic stress on the Alpine Fault, New Zealand. J. Geophys. Res. 84 (No. B12), 6770-6782

Schwinner, R.G. (1924). Scherung, der Zentralbegriff der Tektonik. Cbl. Miner. Geol. Paläont. 469-479

Sciama, W. D. (2012/1959) The unity of the Universe. Courier Corporation ISBN 0486135896 p. 256.

Scoppola, B. Boccaletti, D. Bevis, M. Carminati, E. Doglioni, C. (2006). The westward drift of the lithosphere: A rotational drag? Geol. Soc. Am. Bull. 118/1-2, 199-209. Doi: 10.1130/B25734.1.

Scotese, C.R. (1994). Paleogeographic maps. In: Klein, G. D. ed. Pangea: paleoclimate, tectonics, and sedimentation during accretion, zenith, and breakup of a supercontinent. Geological Society of America Special Paper, 288.

Scotese, C.R. (2014). Atlas of Permo-Carboniferous Paleogeographic Maps (Mollweide Projection), Maps 53-64, Vol. 4, The Late Paleozoic, PALEOMAP Atlas for ArcGIS, PALEOMAP Project, Evanston, IL.

Seclaman, M. (1982). Semnificatia genetica a liniatiilor minerale in sisturile cristaline din Carpatii Meridionali. St. Cerc. Geol. Geofiz. Geogr.Ser. Geol. 27,8-17.

Seebeck, T.J. (1826). Über die magnetische Polarisation der Metalle und Erze durch Temperaturdifferenz. Ann. Phys., 82/3, 253-286.

Shannon, M. C. & Agee, C. B. (1998). Percolation of core melts at lower mantle conditions. Science 280, 1059 – 1061.

References

Shehu, V. (1971). The age and origin of the porphyry granite of Fierza. (In Albanian).Bul.Of Sc. Tirana Unv.No 1 p 127 - 141.

Shehu, V. (1988). Developing Earth. (In Albanian). Tirana, Albania. Sht. Bot. 8 Nëntori, 180.

Shehu, V. (2004). The Earth, a sample of universe in our hands, according to the Earth expansion through growing and developing processes. New Concepts in Global Tectonics. Urbino Italy: Workshop, Aug. 29- 31.

Shehu, V. (2005). The Growing and Developing Earth. No. Charleston, S.C.: BookSuege, LLC (2005), ISBN 1-4196-1963-3, USA, 218.

Shehu, V. (2009). The Growing and Developing Earth. (In Albanian).Tiranë, Albania: Sht. Bot. Dudaj. 361.

Shehu, V. (2012/2011). Earth Expansion through Activity of the Earth Core-Kernel as an active cosmic Object. In: The Earth Expansion Evidence, A challenge for geology, geophysics and astronomy. Selected Contributions to the Interdisciplinary Workshop, (held in Erice, Sicily, Italy 4-9 October. 2011). 243-262. Post-conference publication edited by GiacarloScalera (editor in chief), EnzoBoschi, and Stefan Cwojdziñski. 263-273. Rome.

Shehu, V. (2016). The Earth's Core, an Energetic Cosmic Object. Printed by Create Space, An Amazom.com Company. USA 2016. 80p. https://www.amazon.ca/Earths-Core-Energetic-Cosmic-Object/dp/1512290874.

Shen, W.B, et al. (2008). The expanding Earth: evidences from temporary gravity fields and space geodesic GEPH. Research Abstracts V. 10 EGU2008-A-0473.

Shields, O. (1979). Evidence for initial opening of the Pacific Ocean in the Jurassic. Paleogeography, Paleoclimatology, Paleoecology 26, 181-220.

Shields, O. (1997). Is plate tectonics withstanding the test of time? Annali di Geofisica, Vol XL, 1-8.

Smiley, C.J. (1992). Plaeofloras, faunas, and continental drift: Some problem areas. In: S. Chatterjee and N. Hotton (Eds). New Concepts in Global Tectonics. Texas Tech. University Press, 241-257.

Smith, A.G. (2006). Tethyan Ophiolite emplacement, Africa to Europe motion, and Atlantic spreading. In: The Tectonic Development of the Eastern Mediterranean Region. A.H.F. Robertson and D. Mountrakis, (Eds.). (London Geographical Society, Special Publication 260, 1-9.

Smith, A.G. and Hallam, A. (1970). The fit of the southern continents: Nature, 225, 139-144.

Smith, A.G. Briden, J.C. and Drewry, G.E. (1973). Phanerozoic World Maps. In Hughes, N.F. Organisms and Continents through time. Special Papers in Palaeontology. 12, 1-43.

Smith, A.G. Hurley, A.M and Briden, J.C. (1980). Phanerozoic Palaeocontinental World Maps. Cambridge University Press Earth Science Series. 107 pp.

Smith A. G. Smith D. G. & Funnell B. M. (1994). Atlas of Mesozoic and Cenozoic coastlines. Cambridge University Press.

Soja, C.M. Antoshkina, A.I. (1997). Coeval development of Silurian stromatolite reefs in Alaska and the Ural Mountains: Implications for paleogeography of the Alexander terrane. Geology, 25/6, 539-542.

Spencer, E.W. (1977). Introduction to the Structure of the Erath. McGraw-Hill, Paperback, 640p.

Steiner, J., (1967). The sequence of geological events and the dynamics of the Milky Way galaxy. Jour. Geol. Soc. Australia, 14, 99-132.

Steiner, L. (2014). Von der alpinen Schub- zur Gleitdecke. (From Alpine thrust nappe to downsliding thrust sheet). Z. geol. Wiss., 41-42, 185-196.

Steinhorsson S., Thoraninsson S. (1997). Iceland. In: Moores E.M. and Fairbridge R.W. (eds.) Encyclopedia of European and Asian Geology. Chapman & Hall, London, 341-352.

Stern and Gerya (2018) Subduction initiation in nature and models: A review, Tectonophysics 746, 173-198.

Stevens, G. (1988). John Bradley: a New Zealand pioneer in continental drift studies. Geol. Soc. New Zealand Newsletter, No 17: 30–38. Quoted in Frankel (2012) Volume II.

Strick, J.E. (2015). Wilhelm Reich, Biologist. Harvard University Press, Cambridge, MA, 487 pp.

Stille, H. (1936). The present tectonic state of the Earth. Bull. Am. Assoc. Petrol. Geol. 20, 849-80.

Storetvedt, K.M. (1997). Our evolving planet: Earth history in a new perspective. Alma Mater, Bergen, pp. 456.

Storetvedt, K.M. (2010). Falling plate tectonics–rising new paradigm: salient historical facts and current tuation. NCGT Newletter, 55, 4-34.

Strong, D.F. Hanmer, S.K. (1981). The leucogranites of southern Brittany: origin by faulting, frictional heating, fluid flux and fractional melting. Can. Mineralogist, 19, 163-176.

Strutinski, C. (1987). Strike-slip faults – what are they really standing for? General features with exemplifications from the Romanian

Carpathians. Studia Univ. Babes-Bolyai, Geologia-Geographia, XXXII/2, 47-59.

Strutinski, C. (1990). The importance of transcurrence phenomena in mountain building. In: Critical Aspects of the Plate Tectonics Theory, Volume II (Eds. V. Belousov et al.), Theophrastus Publ. S.A. Athens, 141-166.

Strutinski, C. (1994). An orogenic model consistent with Earth expansion. In: Frontiers of Fundamental Physics (Eds. M. Barone, F. Selleri), Plenum Press, New York, 287-294.

Strutinski, C. (1997). Causal Relations between Crustal Transcurrent Systems and Regional Metamorphism, with Reference to the Upper Proterozoic - ?Cambrian Formations of Central Dobrogea. Doctoral Thesis (Unpublished, in Romanian), Universitatea Bucuresti, 288p

Strutinski, C. (2012). Contradictory aspects in the evolution of life hinting at gravitational acceleration through time. In: The Earth Expansion Evidence. A Challenge for Geology, Geophysics and Astronomy. (Eds.: G. Scalera, E. Boschi, S. Cwojdzinski). Selected contributions to the Interdisciplinary Workshop of the 37th International School of Geophysics EMFCSC, Erice (4-9 October 2011), Aracne Editrice, Rome, 343-364.

Strutinski, C. (2013). Wachsende Schwerkraft – Triebfeder der Evolution? http://www.wachsende-erde.de/web-content/bilder/strut/Strutinski-Wachsende%20Schwerkraft.pdf

Strutinski, C. (2015). Zwei Jahrhunderte Geologie. Von Abraham Gottlieb Werner zu Samuel Warren Carey. http://www.wachsende-erde.de/web-content/2_material6strutinski1.html

Strutinski, C. (2016). Massenextinktionen aus Sicht der Hypothese eines wachsenden Erdballs. http://www.wachsende-erde.de/web-content/bilder/strut/massenextinktionen5.pdf

Strutinski, C. (2017). An alternative view on subduction zones. Powerpoint presentation at the 2nd International Physics Conference, Brussels, 28-30 August 2017. J. Phys. Chem. Biophys. 7/3 (Abstract), 64. Doi: 10.4172/2161-0398-C1-023.

Strutinski, C. (2018a). Fragmentation of the northeastern paleo-Indian oceanic domain by a creeping lithospheric current : Evidence from the Ontong Java Plateau. J. Phys. Chem. Biophys. 8 (Abstract), 74. Doi: 10.4172/2161-0398-C2-031.

Strutinski, C. (2018b). Plattentektonik passé. Wie Mantelströme und Erdwachstum den indopazifischen Raum gestalten. Eigenverlag, Saarbrücken, 127p.

Strutinski, C. (2019). Orogene auf einer wachsenden Erde („Vergiss dein Schulwissen – die Erde ist anders“). Powerpoint to the Presentation held in the Heiner Studt Studio, Hamburg, 18.10.2019.

Strutinski, C. Paica, M. Bucur, I. (1983). The Supragetic Nappe in the Poiana Rusca Massif – an argumentation. An. Inst. Geol. Geofiz, LX, 221-229.

Strutinski, C. Puste, A. (2001). Along-strike shearing instead of orthogonal compression: A different viewpoint on orogeny and regional metamorphism. Himalayan Geol. 22/1, 191-198.

Strutinski, C. Stan, R. Puste, A. (2003). Geotectonic hypotheses at the beginning of the 21st century. In: Why Expanding Earth? A Book in Honour of Ott Christoph Hilgenberg (Eds. G. Scalera, K.H. Jacob), INGV, Rome, 259-273.

Stuart, F.M. Lass-Evans, S. Fitton, J.G. and Ellam, R.M. (2003). High 3He/4He ratios in picritic basalts from Baffin Island and the role of a mixed reservoir in mantle plumes. Nature, 424, 57-59.

Sudiro, P. (2014). The Earth Expansion Theory and its transition from scientific hypothesis to pseudoscientific belief. History of Geo-and Space Sciences, No 135-148. Web: https://www.hist-geo-space-sci.net/5/135/2014/hgss-5-135-2014.pdf.

Suess, E. (1889). Dass Antilitz der Erde, 2, Pt. 3, Die mere der Erdee, Vienna. 704p.

Sullivan, W. (1974). Continents in motion; the new Earth debate. New York, NY: McGraw-Hill.

Sylvester, A.G. (1988). Strike-slip faults. Geol. Soc. Am. Bull. 100, 1666-1703

Szpak, S. Mosier-Boss, P. Gordon, F. Dea, J. Miles, M. Khim, J. Forsley, L. (2008). LENR research using co-deposition. In Proc. the 14th Int. Conf. on Condensed Matter Nuclear Science, Washington, DC (pp. 766–771).

Tarling, D.H. Runcorn, S.K. (1973). Implications of Continental Drift to the Earth Sciences. (NATO Advanced Study Institutes) Symposium, University of Newcastle, England April 1974. Academic Press. Volume 2, 1184 pp.

Tchalenko, J.S. (1970). Similarities between shear zones of different magnitudes. Geol. Soc. Am. Bull. 81, 1626-1640.

Tebbe, J. (1980). Print and American culture. American Quarterly, 32(3), 259–279.

Tharp, M., Frankel, H. (1986). Mappers of the deep. Natural history. New York NY, 95(010), 48-48.

Thompson, D.W. (1917/1966). On Growth and Form. Cambridge University Press, xiv + 346 pp.

Thomson, W. (1854). Thermo-electric currents. Trans. Roy. Soc. Edinburgh, 21, 123-171.

Turcotte, D.L., Oxburgh, E.R. (1973). Mid-plate Tectonics, Nature 244, 337-339.

Tuttle, R.J. (2012). The Fourth Source: Effects of Natural Nuclear Reactors. Universal Publishers, 580p.

Van Andel, T.H. 1984. Plate Tectonics at the threshold of middle age. Geologie en Mijnboaw, 63, 337-341.

Vanderhaeghe, O., Teyssier, C. (1997). Formation of the Shuswap metamorphic core complex during late orogenic collapse of the Canadian Cordillera: Role of ductile thinning and partial melting of the mid- to lower crust. Geodinam. Acta, 10/2, 41-58. Doi: 10.1080/09853111.1997.11105292

Vanderhaeghe, O., Burg, J.P., Teyssier, C. (1999). Exhumation of migmatites in two collapsed orogens: Canadian Cordillera and French Variscides. In: Exhumation Processes: Normal Faulting, Ductile Flow and Erosion (Eds. U.Ring, M.T. Brandon, G.S. Lister, S.D. Willett), Geol. Soc. London, Spec. Publ. 154, 181-204.

Van der Voo, French, A.R. (1974). Apparent polar wandering for the Atlantic-bordering continents: Late Cambrian to Eocene. Earth Science Review. 10, 99-119.

Van Hinsbergen, D.J. Steinberger, B. Doubrovine, P. V. and Gassoller, R. (2011). Acceleration and deceleration of India-Asia convergence since Cretaceous: Roles of mantle plumes and continental collision. Jour. Geophysics Research, 116, doi: 10.1029/02010JB 008081.

Van Steenis, C.G.G.J. (1963). Pacific Plant Areas, Vol. 1, Monograph 8, Manila: Natonal Institute of Science and Technology.

Vauchez, A. Nicolas, A. (1991). Mountain building: strike-parallel motion and mantle anisotropy. Tectonophys. 185, 183-201

Veevers, J.J., Powell, C. McA. and Johnson, B.D. (1980). Sea-floor constraints on the reconstruction of Gondwanaland. Earth and Planetary Science Letters. 51, 435-444.

Verhoogen, J. (1980). Energetics of the Earth. National Academy of Sciences, Washington, D.C. 139p.

Verma, O. and 4 Others. (2016). Historical biogeography of the Late Cretaceous vertebrates of India: Comparison of Geophysical and Paleontological data. In: A. Khosla and S. G. Lucas (Eds).Cretaceous

Period Biotic Diversity and Biogeography. Bull. New Mexico Museum Natural History and Sciences, 71, 317- 330.

Vine, F.J., Matthews, D.H. (1963). Magnetic Anomalies over Oceanic Ridges. Nature London 199, 947-949.

Vogel, K. (1983). Global Models and Earth expansion. In Carey, S.W. The Expanding Earth – A Symposium. Sidney, 1981. University of Tasmania 17-27.

Vogel, K. (1984). Beiträge zur Frage der Expansion der Erde auf der Grundlage von Globenmodellen. Z. geol. Wiss. 12, 563-573.

Vogel, K. (1990). The expansion of the Earth - an alternative model to the plate tectonics theory. In: Critical Aspects of the Plate Tectonics Theory; Volume II, Alternative Theories. Theophrastus Publishers, Athens, Greece, 14-34.

Vogel, K. (2003). Global models of the expanding Earth. In Scalera, G and Jacob, K-H. (Editors) 2003. Why Expanding Earth? A book in honour of Ott Christoph Hilgenberg. INGV publisher Roma, 351-356.

Vogel, K. (2012). Contribution to the Question of Earth Expansion Based on Global Models. In: The Earth Expansion Evidence, A challenge for geology, geophysics and astronomy. "Selected Contributions to the Interdisciplinary Workshop," (held in Erice, Sicily, Italy 4-9 October. 2011). Post-conference publication edited by GiacarloScalera (editor in chief), EnzoBoschi, and Stefan Cwojdziñski. 161-172. Rome.

Wallin, E.T. Noto, R.C. Gehrels, G.E. (2000). Provenance of the Antelope Mountain quartzite, Yreka Terrane, California: Evidence for large-scale late Paleozoic sinistral displacement along the North American Cordilleran margin and implications for the mid-Paleozoic fringing-arc model. Geol. Soc. Am. Bull. Spec. Paper 347, 119-131. Doi: 10.1130/0-8137-2347-7.119.

Walther, H.J., von Gehlen, K., Haditsch, G., Maus, H.J. (1999). Lagerstättenkundliches Wörterbuch. GDMB, Clausthal, 688 pp.

Wang C. Jin A. (2006). Mechanism of the Mafic Dyke Swarms Emplacement in the Eastern Block of the North China Craton. In: Hou G. and Li J. (eds.) Precambrian Geology of the North China Craton. Journal of the Virtual Explorer, Electronic Edition, ISSN 1441-8142, vol. 24, paper 3, doi:10.3809/jvirtex.2006.00161.

Wegener, A. (1912). Die Entstehung der Kontinente und Ozeane. Geologische Rundschau 3, 276-292.

Wegener, A. (1912). The Origins of continents and oceans. (Dover Earth Science: 1915). Originally presented at A Yearly Meeting of the German Geological Society (6 January, 1912).

Wegener, A. (1915). Die Entstehung der Kontinente und Ozeane (The Origin of Continents and Oceans). Sammlung Vieweg Nr. 23, Braunschweig, 94p.

Wegener, A. (1924). The Origin of Continents and Oceans. (trans. 3rd ed.). Methuen, London; Dutton & Co. New York, pp.212.

Wegener, A. (1966). The origin of continents and oceans (trans. 4rd ed.). Dover Publications, New York.

Welsh, W.E. Doyle, L.R. (2013). World with two stars. Scientific American 309 (5): 4. (Nov. 2013). 40-47. DOI: 10. l038/scientific American 1113-40.

Wenbin S, and Sung-Ho, N. (2017). Atmospheric acceleration and Earth expansion deceleration of the Earth rotation. Geodesy and Geodynamics. 8, 421-426.

Wertenbaker, W. (1974). The Floor Of The Sea: Maurice Ewing and the Search to Understand the Earth. ISBN: 978-0316931212.

Wilhelm Reich Infant Trust. https://www.wilhelmreichtrust.org/biography.html.

Winchester, S. (2001). The map that changed the world. Viking, pp.338.

Wingate, M.T.D., Pisarevsky, S.A., Evans, D.A.D. (2002). Rodinia connections between Australia and Laurentia: no SWEAT, no AUSWUS?, Terra Nova 14, No. 2, 121-128.

Wood, J.A. (1968). Meteorites and the origin of planets. New York: The McGraw Hill Companies, 117.

Wood, R.M. (1979). Is the Earth getting bigger! Some geologists believe that our world is expanding. New Scientist 8 February 1979. p 387-388.

Wood, R.M. (1985). Dark Side of the Earth. Harper Collins Publishers.

Wright, L.A. Troxel, B.W. (1969). Chaos structure and Basin and Range normal faults: Evidence for a genetic relationship. Geol. Soc. Am. Abstracts with Programs, 1/7, 242.

Wright, L.A. Troxel, B.W. (1973). Shallow fault interpretation of Basin and Range structure, southwestern Great Basin. In: Gravity and Tectonics (Eds. K.A. de Jong, R. Scholten), Wiley, New York, 397-407.

Xiao W., Songlian A O., Yang L, Chunming H Bo W, Zhang J E, Zhang, Z Y, Rui L, Zhan Yu C and Soong S H (2017) Anatomy of composition and nature of plate convergence: Insights for alternative thoughts for terminal India-Eurasia collision. China Earth Sciences, 60, 1015-1039.

Yano, T. Vasiliev, B.I. Choi, D.R. et al. (2011). Continental rocks in Indian Ocean. NCGT Newsletter 58, (Australia NGCT.org, 2011). 09-28.

Yuecheng, C. et al. (1998). A new interpretation of the Himalayan orogenic belt. Chinese Science Bulletin, 43.1, 83-84. DOI: 10.1007/BF02885523.

Young, C. J. Lay, T. (1987). The core-mantle boundary. Earth Planet Science Annual Review, 15, (1987).25-46.

Young, T.E. (2010). Cloudy with a chance of stars. Scientific American V. 302. 34-41.DOI:10.1038/scientific American 0210-34.

Zagorevski, A. et al. (2008). Tectonic architecture of an arc-arc collision zone, Newfoundland Appalachians. Annals of Geophysics, Supplement to V.49, No. 1. Special Paper #436 in Draut A. Clift, P.D. and D.W. Scholl (Eds.). Formation and application of the sedimentary record in arc collision zones. (Boulder, CO: Geographical Society of America, Inc. Special Paper #346,). 309-334.

Zheng, H. Powell, C.M. Zhou, Z.A.J. Dong, G. (2000). Pliocene uplift of the northern Tibet Plateau. Geology, 28, 715-718.

Zolensky, M.E. et al. (2006). Mineralogy and petrology of Comet 81 P/Wild 2 Nucleus Samples. In Science, V. 314, No. 5806. (Stanford, CA: Highwire Press, 2006).1735-1739.