前寒武纪－寒武纪界线附近的撞击假说及其对生物圈的影响

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摘 要：根据化石记录可知，大量复杂生物类群迅速出现在早寒武世，这就是所谓的寒武纪生命大爆发。在此之前，有距今6亿年前的前寒武纪末埃迪卡拉生物群化石出现，此后的70 ～ 80 Ma里，生命就以上升了一个数量级的速率演化。这些在原始地层中看似迅速出现的化石，最早在19世纪中期就有所记录，达尔文认为，这是对他提出的进化论的自然选择观点的主要反对证据之一。

有关新动物群的出现及演化长期困惑着地学界，集中在以下三点：在前寒武纪－寒武纪界线附近或早寒武世这个相对较短的时期内，存在着生命大爆发。是什么引起了这样的快速演化事件？这对于生命的起源与演化将意味着什么？对"寒武纪生命大爆发"的强烈兴趣还启发了20世纪70年代对布尔吉斯页岩化石记录的研究。不久之后，中国的澄江生物群包括对它后续的研究又很好地支持了生命大爆发。

在前寒武纪－寒武纪界线附近究竟发生了什么？随着笔者对寒武纪事件越来越多的了解，积累的数据使得很多原先提出的假说都变得不太可能了。通过作者对地球环境的改变和寒武纪生命大爆发详实的研究，发现这种改变是可以由撞击事件引起的。在对寒武纪时期的地球进行了详细的研究之后，笔者提出了新的见解。

前寒武纪晚期，存在大型的陨击事件。碰撞的高温结束了大冰期，使生物信息得以交流。同时，撞击启动基因调控机制、释放HSP90变异。一方面，调控基因决定了其他基因的表达，最早的调控基因发现于布尔吉斯页岩中(535 Ma)。另一方面，HSP90原本是积累突变的蛋白，一旦环境突然发生变化，所有DNA突变将得以表达，在短时间内新的生命形式得以进化。并且这种变化是可以遗传的。然后，在新生臭氧层保护与有氧呼吸能量供应下，地球另一端幸存地下生命爆发，产生硬壳及复杂的新陈代谢以适应高温高压。

现代的银河系天文理论，即密度波理论，在本文中被应用以试图解释这种撞击背后的天文学诱因。5～6亿年前的寒武纪事件使笔者联想起另外两次仍然存在争议的大规模撞击事件，它们引起的大气变化、水圈变化、生物圈变化、碳酸盐岩变化、磷矿变化都惊人的相似。形成于17亿年以前的Sadbury陨击坑直径为200 km，是最大陨击坑之一；23亿年以前(23.3 ～ 22.88亿年)地质环境(沉积圈、生物圈、水圈、大气圈)发生了由地外因素引起的灾变。灾变后，火山活动明显减弱，富氧大气圈形成，生物演化出现飞跃，叠层石开始广泛发育，碳酸盐岩在各大陆大量沉积，第一次全球性磷矿期开始发育。根据几处23亿年左右陨落的大量消溶型铁质宇宙尘的发现，推论该灾变的起因是与陨击作用有关的宇宙事件，且地表23亿年前的泛火山运动和月岩年龄分布(23 ～ 25亿年)以及月表陨石坑构造等表明：23亿年前，地外物体对地球的冲击作用非常强烈。再考虑到6 500万年前的契科苏博鲁陨击事件，也就是说，在已经得到广泛承认的和存在争议但有事实支持的地外灾变事件中规模最为巨大的三次撞击事件符合5 ～ 6亿年这一大周期。5 ～ 6亿年正是太阳系扫过银河系四条主旋臂一次所用的时间：太阳绕银河一周的时间大约是290个百万年。而由于在太阳绕银河转的时候，银河系的四条大旋臂同样旋转，并且其螺旋势场的角速度约是太阳系的一半，最终叠加的结果就是这样的一个大周期。密度波理论表明，旋臂处质量密度非常大，并且形成旋臂的螺旋引力场将对太阳系产生影响，诱发撞击事件。

本文通过前人定性证据和笔者实地考察表明，上述假说与当时的绝大多数重要天文事件和地质发现相吻合，广泛的铱异常与位于澳大利亚的大型陨击坑均有发现。对澳大利亚的Acraman陨击坑和MAPCIS陨击坑的基底构造实地分析也表明了前寒武纪末曾经存在过陨击事件。

最后笔者利用计算机模拟了大气圈变化。模拟分两步进行，首先从岩石热分解得出需要的温度与压强数据，而后将数据作为参数用于模拟。数据结果表明撞击区域的大气温度在4 000 K左右，压强为5 600 Bar。撞击增加了大气中二氧化碳和氧气的含量，并强化了臭氧层。这些含量的变化与地质上的记录一致。

关键词：寒武纪；生命大爆发；银河系旋臂；撞击事件

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Possible Impact at Precambrian–Cambrian Boundary and Its Influence on Biosphere

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Abstract: After a thorough research on the Earth's circumstantial changes and the great evolution of life in the Cambrian period, the authors propound such a hypothesis: During the Late Precambrian, about 500 ~ 600 Ma, a celestial body impacted the Earth. The high temperature ended the great glaciation, facilitated the communication of biological information. The rapid change of Earth environment enkindled the genesis-control system, and released the HSP-90 variations. After the impact, benefited from the protection of the new ozone layer and the energy supplement of the aerobic respiration, those survived underground life exploded. They generated carapaces and complex metabolism to adjust to the new circumstance of high temperature and high pressure. That's the Cambrian explosion. This article uses a large amount of analyses and calculations, and illustrates that this hypothesis fits well with most of the important incidences in astronomic and geologic discoveries.

Keywords: Cambrian; Life evolution; Milky Way spriral arms; impact

1 Introduction

The life explosion was the seemingly rapid appearance of most major groups of complex animals in the early Cambrian, as evidenced by the fossil record. This was accompanied by a major diversification of other organisms. It was discovered that the history of life on earth goes back at least 3 550 million years: rocks of that age at Warrawoona in Australia contain fossils of stromatolites, stubby pillars that are formed by colonies of micro-organisms [1]. However, before about 580 million years ago (Late Pre-Cambrian), most organisms were simple, composed of individual cells occasionally organized into colonies.

It took almost 4 billion years from the formation of the Earth for the Ediacaran fossils to first appear. Then, over the following 70 or 80 million years the rate of evolution accelerated by an order of magnitude.

The seemingly rapid appearance of fossils in the "Primordial Strata" was noted as early as the mid 19th century [2], and Charles Darwin saw it as one of the main objections that could be made against his theory of evolution by natural selection [3].

The long-running puzzlement about the appearance of the new fauna, seemingly abruptly and from nowhere, centers on three key points: whether there really was a mass diversification of complex organisms over a relatively short period of time during the Precambrian\Cambrian boundary and early Cambrian; what might have caused such rapid evolution; and what it would imply about the origin and evolution of animals.

The intense modern interest in this "Cambrian explosion" was sparked by Whittington [4], who in the 1970s re-analyzed many fossils from the Burgess Shale (see below) and concluded that several were complex as but different from any living animals.

The explosion was supported by Chenjiang Fauna [5,6]. The Chengjiang Fauna, a well preserved fauna, was found in Chengjiang County of Yun-nan Province in 1984. It is this discovery and subsequent researches that confirm the Cambrian Explosion occurred.

The diversity of many Cambrian assemblages is similar to today's [7,8].

Anyhow, the first appearance of the great evolution is the Ediacaran life-forms, which is an attempt of the explosion. The Ediacaran fauna is an assemblage at Precambrian\Cambrian boundary, with a stratotype in Ediacara hill, South Australia. The fauna has now been found on all continents except Antarctica. The organisms of the Ediacaran Period first appeared around 580 million years ago and flourished until the cusp of the Cambrian 542 million years ago.

What happened in the Precambrian\Cambrian boundary?

However, the authors did a thorough research on Earth's circumstantial changes and the Cambrian explosion, and we were surprised that it's an impact which caused the mysterious changes. Investigations revealed the impact fits well with most of the important incidences in astronomic and geologic discoveries.

This paper will illustrate some important parts more clearly by boldface.

2 The Cambrian impact hypothesis and rapid evolution

As our understanding of the events of the Cambrian becomes clearer, data has accumulated to make some hypotheses look improbable. Causes that have been proposed but are now discounted include the evolution of herbivory, vast changes in the speed of tectonic plate movement or of the cyclic changes in the Earth's orbital motion, or the operation of different evolutionary mechanisms from those that are seen in the rest of the Phanerozoic eon.

In the Late Precambrian, the whole Earth was in a long ice age, and moraines were found in all current continents [9-13]. Almost only primal one-celled life could live in such a rigorous environment.

Initially, computer simulations [14-15] pointed out that a giant impact would cause global high temperature and high pressure. We noticed that in Early Cambrian, the second Neoproterozoic global glaciation, Marinoan (~600 Ma) melted, flood inundated the Earth [16-17], implying a huge heat. That's why there were traces of water scouring on ancient continents. Also, just around that time, the Edicaran assemblage firstly appeared. 50 million years later, in the "Cambrian Explosion", metazoan rapidly appeared, formed almost all kinds of life today, and featured by carapaces.

After a thorough research on the Earth's circumstantial changes and the great evolution of life-forms in the Cambrian Period, to shed light upon a number of issues, the authors did propound such a hypothesis:

In the Late Precambrian, about 500 ~ 600 million years ago, a celestial body impacted the Earth. The high temperature ended the great glaciation, facilitated the communication of biological information. The rapid changes of Earth's environment enkindled the genesis-control system, and released the HSP-90 variations.

After the impact, benefited from the protection of new ozone layer and the energy supplement of the aerobic respiration, those survived underground life exploded. They generated carapaces and complex metabolism to adjust to the new circumstance of high temperature and high pressure.

2.1 The meteor craters and the spiral arms

It's the most exciting period in Earth history. Before this research, the authors have noticed a cycle in Earth history. Maybe that's why the impact occurs. There are some giant but disputable events. They are called Astroblems — great impact events. The aftermath of the 4 largest calamities, the considerable and disputable meteorites at 65 Ma, 580 Ma, 1 700 Ma and 2 300 Ma, including atmospheric change, hydrospheric change (Fig. 1), biospheric change and lithospheric change, are surprisingly similar.

65 million years ago, the impact event in Late Cretaceous caused the extinction of dinosaurs [18]. In Yucatan, the crater's diameter reached 180 kilometers.

580 million years ago, the Acraman meteor event, whose crater in South Australia is confirmed, has a 160 km crater diameter. This meteor crater is one of the three largest meteor events ever discovered [19]. The crater is just in the same time with the Cambrian impact.

1.7 billion years ago, Sudbury, the meteor crater's di-

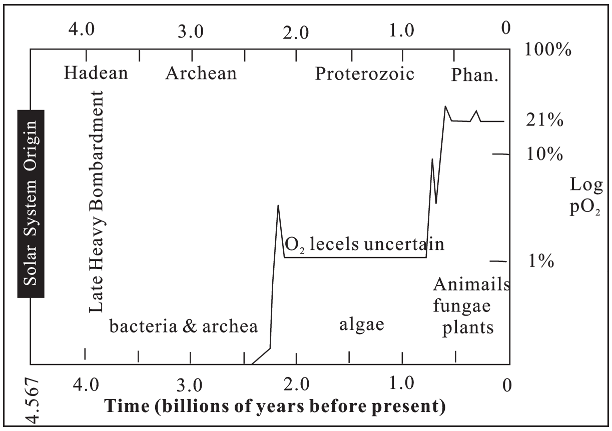

Fig. 1 O_2's increase during the Earth's history [22].Life is not the main reason of oxygen's increase. The oxygen's level almost kept constant in Proterozoic and Phanerobiotic. The rapid increase occurred at 2 300 Ma and 600 Ma.

ameter reached 200 kilometers, which is one of the three largest meteor events ever discovered[20].

2.3 billion years ago: "Geological environment (lithosphere, ecosphere, hydrosphere, atmosphere) suffered a catastrophe caused by extraterrestrial diathesis. After that, oxygenic atmosphere formed, life evolution occurred... stromatolites widely developed...carbonatites largely deposited in all continents..."[21].

According to the former mentor's study in Peking University[21], it should be a large meteor event.

In both confirmed and disputable meteor catastrophes, the four largest ones indicated a cycle of two cosmic years.

65 Ma－580 Ma－(Vacancy)－1 700 Ma －2 300 Ma

We will find the period is decreasing from 600 Ma (23－17＝6) to 535 Ma (6－0.65＝5.35).In fact the cosmic year is decreasing, from 300 Ma in 2 billion years ago to the present data of 250 Ma[23]. It is just the time our Solar System needs to pass the four major swing arms once.

We all know the time Solar System needs to move around the galaxy once. It is called a cosmic year. And while the Solar System is moving, the four major swing arms of the galaxy are circling round too. Furthermore, the velocity of the screwy gravitational field was just half of the Solar System's velocity. Hereby the final result is—the time our Solar System needs to pass the four major swing arms once is neither more nor less than 2 cosmic years[24].

There is an abnormal gravitational origin in one of the major swing arms. The Solar System is a 2-body system. A planet only has gravitational operation with the Sun. The gravitation between planets is trivial. All 2-body celestial systems have analytic state and its macroscopical state can be calculated. But when the Solar System passes the abnormal gravitational field, according to modern Density wave theory, a strong force from spiral potential works, resulted in a 3-body celestial system. A 3-body gravitational systemis a state of chaos. The state is confused and impacts become possible. Maybe that's why there are always some "aura events" or "aura stratums" before important catastrophic periods in Earth history. Here is a structure map of the Milky galaxy, presented in Fig. 2.

2.2 The mechanism of impact-related life evolution

The impact destroyed the former and moldering life system. Many advantages created by the giant impact promoted the new life-form's evolution. There is considerable evidence to support this statement.

(1) The impact ended the glacier: During the ice age seas were blocked, life couldn't exchange genetic information. Then the collisional high temperature and high pressure ended the glacier, and made the exchange of genetic information possible and convenient.

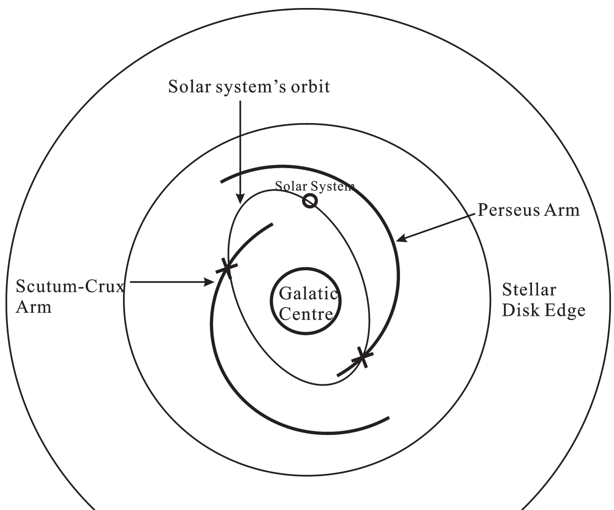

Fig. 2 "Plan view" of the Milky Way as seen from its north pole. The locations of the Galactic Center, Sun, and spiral arms are indicated.

(2) The impact increased oxygen level：

Berner and Canfield [25]：In the Precambrian period the concentration of oxygen in the atmosphere was quite low.（The deposition of Bar Ferrite, the oceanic anoxia, the uranous conglomerate also supported their result.）But around 600 Ma, the level jumped to 7%～10% of the current value. Finally, in Late Cambrian, it reached the current level. The ozone increased so rapidly, indicating a tremendous event. Such a sudden increase implied a collisional thermal decomposition of the seawater. After the decomposition, the hydrogen would escape from the atmosphere for its diffusion velocity which is much faster than any other gas. Thus the oxygen was reserved. Paul G. Falkowski and his research group analyzed the isotopic records of carbon and sulfur in the primal oceanic deposition and got the oxygen level in the past hundreds of million years. The oxygen level at 600 Ma was 20%, very close to the current level [26]. The efficiency of aerobic respiration is 18 times of anaerobic respiration. The energy for an evolution was created.

(3) The impact generated ozone layer：The ozone layer appeared in the Cambrian period [27]. Since the impact caused the high temperature and generated enough oxygen, the reactions below would happen: O_2=2O, O_2+O=O_3. The ozone layer is one of the most effective protections of life.

(4) The impact activated the gene-control system ：The control gene determined the expression of other genes [28-29]，and it is the key to the explosion. The earliest control gene ever discovered was in Burgess Shale（535 Ma）.

(5) The impact activated Heat-shock protein 90（HSP90）：HSP90 accumulates mutations. As soon as the environment suddenly changed, all DNA mutations would express. Then the new life-forms would evolve with different morphosis in a short period. These diversions can be inherited [30].The heat-shock protein Hsp90 supports diverse but specific signal transducers and lies at the interface of several developmental pathways. Rutherford and Lindquist [30] reported that when Drosophila Hsp90 is mutant or pharmacologically impaired, phenotypic variation affecting nearly any adult structure is produced, with specific variants depending on the genetic background and occurring both in laboratory strains and in wild populations. Multiple, previously silent, genetic determinants produced these variants and, when enriched by selection, they rapidly became independent of the Hsp90 mutation. Therefore, widespread variation affecting morphogenic pathways exists in nature, but is usually silent; Hsp90 buffers this variation, allowing it to accumulate under neutral conditions. When Hsp90 buffering is compromised, for example by temperature, cryptic variants are expressed and selection can lead to the continued expression of these traits, even when Hsp90 function is restored.

(6) The impact resulted in a quick evolution of carapaces：1) With the advantages above, many new kinds of algae developed, contributed to the enrichment of phosphor and prepared enough material for the genesis of carapaces；2) Since a large amount of ammonia was created (a small part of the hydrogen generated by the thermal decomposition could combine with nitrogen , became the alkaline air，then dissolved in sea and became ammonia), the ocean's pH became alkalescence. Then it's much harder for animals to excrete excrescent resultants out, and carapaces were formed. 3) High temperature and high pressure compelled the new life to generate carapaces, or they would be eliminated through selection.

In the Cambrian period, the ancient Australia continent was at the equator, but researchers found the remnant of glacier there [9-12,31]. The analyses of moraine also showed the distribution of the glacier included all continents, and were at low latitudes [9-11,31-34]. Accordingly, at that time the axis of rotation is close to the current equator until the impact occurred. The whole process of impact is shown in Fig. 3.

After a giant impact, the axis of impact would become the axis of rotation, which can be explained by the energy minimum principle of a rotational mode and the parallel axis theorem.

Hays et al. [35] confirmed the calculation by Milankovitch：the more acclivitous the axis of rotation is, the colder the climate would be. This can explain the simulation result of Neoproterozoic global glaciation [36]. It is George E. Williams who first put forward the hypothesis

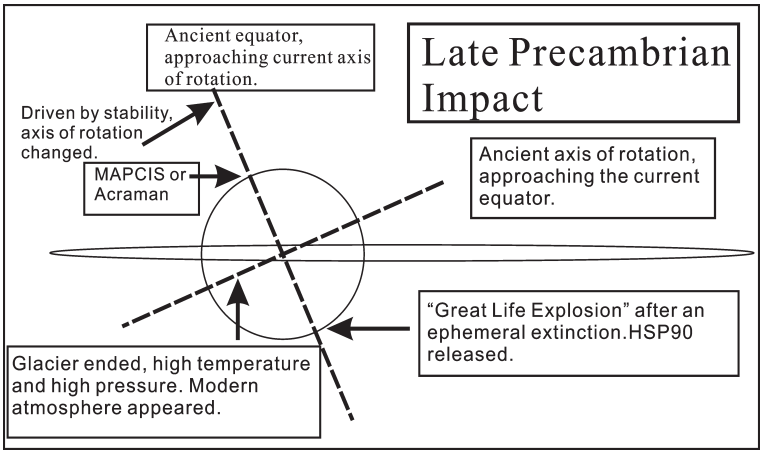

Fig. 3 Illustration of the Late Precambrian impact

that in Late Precambrian the Earth was inclining [37]. Williams disregarded many oppugnations and published his work with courage.

Now, the impact hypothesis could explain these oppugnations:

(1) The deposition of Bar Ferrite—since the oxygen was suddenly generated by thermal decomposition, the Neoproterozoic atmosphere before the impact is neutral, and the Bar Ferrite could exist.

(2) The carbonate cap—the impact would cause high temperature.

(3) C13 negative excursion—the impact exterminated the former ecosystem.

(4) Once the obliquity of the ecliptic got smaller, it won't change because of the gravity between the Earth and the Moon [22]—the impact just ended this self-stability.

(5) Williams's mode cannot explain the high level of ferrite and iridium in the carbonate cap [22]—the extraterrestrial impact increased the concentration of ferrite and iridium.

3 Traces of Late Precambrian impact

(1) Iridium anomaly

There was iridium anomaly in the Meishucun section where Cambrian explosion was discovered [38-39]. The Ir concentration measured by China Institute of Atomic Energy in 1985 reached 3.97×10^{-9}.

In the middle of Sanxia and Chenjiang, researchers also discovered the iridium anomaly by analyzing the sample of Precambrian-Cambrian boundary [38].

Such anomalies are widely witnessed in China [40].

In many Cambrian layers of China developed black shales with Ni-Mo contained. The iridium anomaly reached 11～13 mg/t there. Such shales were also discovered in worldwide regions [41].

Bodiselitsch et al. [42] found iridium anomalies at the base of cap carbonates in three drill cores from the Eastern Congo craton. Ir anomalies were found at the base of all cap carbonates after the Marinoan and Sturtian glaciations in the Nguba and Kundelungu Groups at Kipushi, as well as after the Sturtian glacial deposits in the Nguba Group at Chambishi. Substantial Ir anomalies up to almost 2×10^{-9} mark the base of the cap carbonate deposits. Their geochemical data clearly indicate that the (substantial) Ir anomalies at the base of the cap carbonates are derived from extraterrestrial sources, whereas the other (smaller) Ir anomalies disappear or are greatly diminished when ratios with other elements are used. The carbonate succession over the CGCCT Ir anomaly shows very high Ir/Fe, Ir/Al, and Ir/Cs ratios and low Co/Ir and Cr/Ir ratios, as well as Ir abundances of 45 to 60×10^{-9}. This is very high, if we assume that cap carbonates precipitated very rapidly [13]

(2) Acraman meteor crater

There are three huge meteor craters of which the diameters were ≥160 km. Among these, the Acraman meteor crater (580 Ma) in Australia is confirmed [19].The structure has an inner depressed area about 30 kilometers in diameter that contains the Lake Acraman salina, an intermediate depression or ring about 90 kilometers in diameter, and a possible outer ring approximately 160 kilometers in diameter. Outcrops of dacite in Lake Acraman are intensely shattered and contain shatter cones and multiple sets of shock lamellae in quartz grains. The Acraman structure is the largest probable impact structure known in Australia and is the likely source of dacitic ejecta found in late Precambrian marine shales some 300 kilometers to the east. The presence within Lake Acraman of intensely shattered basement rocks containing features ascribed to shock-metamorphism [43-44] argues strongly that the Acraman depression marks the site of a major hypervelocity impact. The inferred Acraman structure has four major elements: (i) a possible outer ring 150 to 160 km in diameter; (ii) an intermediate depression or ring about 90 km in diameter; (iii) an inner depression about 30 km in diameter; and (iv) a possible central uplifted area within Lake Acraman. Taking the diameters of the outer two rings as 90 and 160 km gives a ring spacing ratio of 1.8, which is in agreement with ratios determined for other multiringed structures of probable impact origin [45-46]. It is the abnormal gravitational field which caused the impact events, primary or concomitant. Maybe the Acraman is a concomitant event.

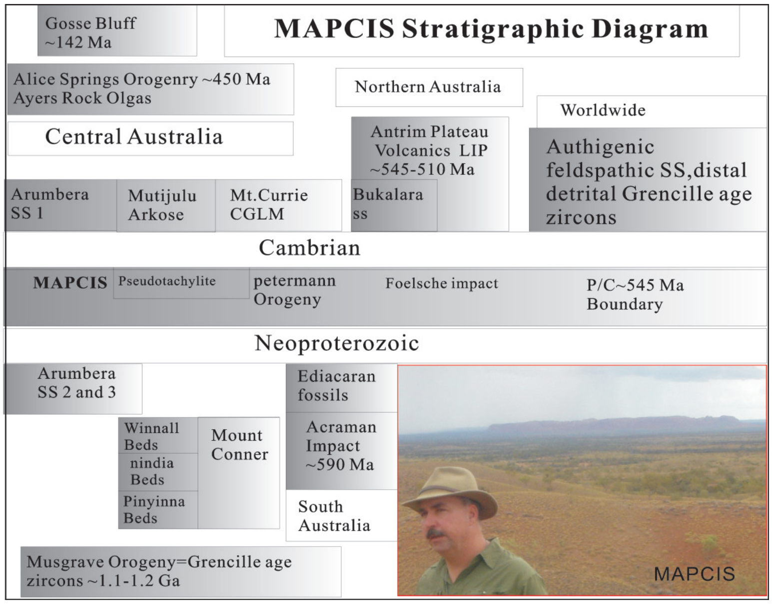

Fig. 4 MAPCIS stratigraphic diagram. MAPCIS probably occurred just before the Precambrian/ Cambrian Boundary. Further research is needed to refine this dating. The photo presents a corner of MAPCIS and the second author (Dr. Connelly) of this paper

(3) MAPCIS impact crater and Cambrian impact ejecta deposits in Australia

MAPCIS (Massive Australian Precambrian/Cambrian Impact Structure) is the largest known terrestrial impact structure and is dated to approximately 545 Ma. MAPCIS is a complex multiple ring impact structured with the buried center located at 25° 32'55.66"S, 131° 23' 21.50"E approximately equidistant between Uluru/Ayers Rock and Mt. Conner, see Fig. 4.

The 2 000 km outermost ring was visualized from a 2007 satellite Google Earth image after a rare rainy season in central Australia transformed the usual monochrome reddish desert to a multihued bloom which temporarily highlighted the crater ring. There are significant concentric magnetic [47] and gravitational anomalies [48] at the center consistent with impact origin that lies underneath a central MASCON. On the 2002 magnetic intensity map of the Uluru/Ayers Rock region [49] there is a comet shaped excavation in the crystalline basement that runs NNE to SSW ending at contact with the Musgrave Block. Regional geology, lineaments, forbidden zones and smaller coeval impacts [50] are consistent with a NNE to SSW trajectory of an oblique impact.

Large pseudotachylite deposits are considered diagnostic evidence, for the biggest impacts [51]as are evident at the Vredefort and Sudbury impacts. Pseudotachylite deposits in the direct downrange angle of MAPCIS center are the largest known in the world. The pseudotachylite stretches over 300 km from the Tomkinson Ranges in Western Australia to Mt. Cuthbert where it enters the Northern Territories, with widths up to 2 km. The Pseudotachylite deposits can be found in arcuate deposits around MAPCIS center and in radial deposits which converge at MAPCIS center.

The pseudotachylite postdates all other lithologies and structures and is not associated with any single fault or structure[52].

The dating of MAPCIS is based on regional stratigraphic relationships and on individual crystals located directly downrange between MAPCIS center and the pseudotachylite[53]. The basement target rock of 1Ba Grenville age was violently exhumed, activating all the faults in the Musgrave block, which reset ages around these faults to dates between the original age and approximately 545 Ma.The Neoproterozoic beds of Mt. Conner survive the impact and are evidence of the age of the target rock. Acraman~590 Ma ejecta layer is missing at MAPCIS center and directly downrange, yet is intact in protected forbidden zones or deep trenches [54].

Soft bodied Ediacaran fauna of South Australia are preserved in the protected areas at the time of the mass extinction at the end of the Precambrian. MAPCIS is centered in post impact Cambrian Kalkarindji Event flood basalts[55].

This is but a brief synopsis of the most salient information pertaining to MAPCIS. As a newly discovered impact, there is still much to be done.

Also, in the Precambrian shales of Adelaide, South Australia (~ 600 Ma), and the impact ejecta deposits can be traced back to 260 km [43]. A solitary layer of shattered crustal rock fragments has been traced over a distance of 260 kilometers within folded 600-million-year-old Precambrian marine shales of the Adelaide Geosyncline, South Australia. The fragments consist entirely of acid to intermediate volcanics (approximately 1 575 million years old) displaying shattered mineral grains, shock lamellae in quartz, and small shatter cones. Fragments reach 30 centimeters in diameter and show evidence of vertical fall emplacement. Available evidence points to derivation of the rock fragments from a distant hypervelocity impact into the Gawler Range Volcanics at Lake Acraman, approximately 300 kilometers west of the Adelaide Geosyncline. To our knowledge, this is the first record of widely dispersed coarse impact ejecta preserved in a pre-Cenozoic sedimentary sequence.

(4) Discovery of the iron spherules and silicon particles in the White Clay near Precambrian /Cambrian boundary

In the Meishucun section（P∈-∈）,large number of high-silica contained iron spherules and silicon particles which maybe formed in a high temperature were discovered in the White Clay near Precambrian /Cambrian boundary[39, 40, 56] . They directly indicated an extraterrestrial catastrophic event.

(5) Extermination of former life system in the Late Precambrian

The $\delta^{13}C$ rapidly decreased in the Early Cambrian [57], reached the vale, implying an extermination, then rapidly increased, implying the Cambrian Explosion. The analysis of $\delta^{13}C$ value's changes in the 8 important boundary lines of Phanerobiotic showed that the range of $\delta^{13}C$ negative excursion is in direct proportion with the extent of life extermination.

Study of Meishucun micro-fossils showed that more than 70% families and 80% genera categories exterminated in Late Precambrian [40,56]. The $\delta^{13}C$ negative excursion at the P∈-∈ boundary line in Sanxia section and Meishucun section were discovered by Hsu et al. [38,58].

4 Chemical and thermochemical calculations

The principle of proving the atmospheric process is clear. If the modern atmosphere generated from the thermal decomposition in the impact, the temperature and pressure obtained from rock's thermal decomposition should be the same with the ones obtained from oxygen's sudden increase and the genesis of the ozone layer.

Sleep [14-15] has modeled the impact of planetesimals--objects as large as 500 kilometers across which were very common in the early Solar System. He found that a huge amount of rock would have been vaporized, lifting the surface temperatures to 3 000° C, turning the oceans into gas and driving off any atmosphere. Such conditions would have been catastrophic for any living things on the land surfaces or in the water. Sleep estimated that the Earth would have taken 2 000 years to restabilise after each impact.

4.1 The temperature and pressure obtained from rock's thermal decomposition

Data 1): In the Late Precambrian (~600 Ma), the level of CO_2 is about twice of current value, but in Late Cambrian, the ratio increased to 18 [59]. The paper suggested the weight of Cambrian atmosphere is close to current data (~5.3×10^{18} kg), then the CO_2 created was about 2.703×10^{16} kg.(5.3×10^{18}(0.51%~0.06%) =2.703×10^{16} kg)

An estimate of the vaporized magma's amount:

$$n \approx n_{CaCO_3} \times 20 = n_{CO_2} \times 20 = 1.23 \times 10^{19} mol$$

According to Sleep's result[14-15], the authors suggested the impact directly influenced an area with a radius of 600 km. In such an area, the atmosphere would participate in the chemical reaction, and the seawater would vaporize(Table 1).

Reaction and formula 1): $CaCO_3=CaO+CO_2$

$$-RTlnK \approx \Delta fHm - T\Delta fSm$$

Dataset was presented below, as Table 1.

Result 1): Above 3 000℃ $CaCO_3$ will decompose completely (K>10^6), thus $T \geqslant 3\,907\,K$.

In the Archeozoic atmosphere, the concentration of CO_2 and N_2 were both 50%. In the Precambrian, there was almost no CO_2, while the level of N_2 was close to 100% [61]. According to Berner [59], in the Early Cambrian, the concentration of CO_2 in the atmosphere is about twice of the current level, but in the Cambrian period, the ratio increased to 18. This may be the direct effect of impact. According to Data 1, the total amount of atmosphere in the effected area should be 4.19×10^{17} mol.

The volume wouldn't change significantly because of the gravity, so the new amount of the gas in the area was 424 times of the former (1.23 × 10^{19} mol from the gasified rock, 4.19×10^{17}mol from the pristine atmosphere of the effected area, 1.698×10^{20} mol from the gasified water). The total amount was 1.775×10^{20} mol.

According to $P=\frac{nRT}{v}$, the air pressure of the effected area was about 5 600 Bar.

4. 2 The excellent accordance of temperature data and the origin of the ozone layer

Data 2) ： The Precambrian atmosphere has little oxygen [31]. The author synthesized results from Berner and Canfield [25] and other researchers. Then the concentration of oxygen suddenly increased and reached 3% ～ 10% of current value. The authors chose the average number 6.5%. First we don't need to care in which form would the oxygen atoms exist,

$$moxygen-atoms=7.93\times10^{16}kg,$$

$$noxygen-atoms=4.96\times10^{18}mol.$$

The well-accepted view told us that the early Cambrian Earth was covered by a large shallow ocean. In a 600^2 πsq.km. area, there should be 3.06 × 10^{18} kg water. When the water boiled away, there should be 1.698 × 10^{20} mol vapor (H_2O) in the atmosphere. Dataset was presented below, as Table 2.

Reaction and formula 2): $2H_2O=2H_2+O_2$ (Normal decomposition), $H_2O=H_2+O$ (Free radical decomposition in a high temperature), $O_2+O=O_3$

$$\Delta rHmT=\Delta rHm^{\Theta}+\int_{298.15}^{T}\Delta\ ,$$

$$\Delta rSmT=\Delta rSm^{\Theta}+\int_{298.15}^{T}\frac{\Delta Cp}{T}dT\ .$$

Result 2): The critical temperature of normal decomposition is 5 450 K, while the one of free radical decomposition is 4 759 Km (much lower). So the decomposition of water would also produce free oxygen atoms at 4 000 K! Supposing all the water reacted as normal decomposition, T = 3 432 K; then if all the water reacted as the free radical decomposition, T = 4 111 K. The temperature obtained from different methods matched well. The temperature was about 4 000 K, while the pressure was about 5 600 Bar.

Since the average temperature was so high, and many free oxygen had generated, there must be the chemical reaction $O_2+O=O_3$. That's just the origin of the ozone layer.

Data 3): In the standard condition, for O_3, $\Delta rH_m=142\,200\,J$, $\Delta rS_m=237.6\,J$, $C_{P,m}=38.16\,J$. Convert to 3 772 K, then use $-RT\ln K=\Delta H-T\Delta S$ and got K = 4.418 × 10^{-7}, The simplified expression of K $\Rightarrow nO_3=1.401\times10^{-23}\times nO\times2nO_2$ The sum of nO

Table 1 Data from "Thermochemical Data of Pure Substances" [60].

Substance	$\triangle_f H_m$(J·K^{-1}mol)	$\triangle_f G_m$(J·K^{-1}mol)	S_m (J·K^{-1}mol)
$CaCO_3$	-1206.9	-1128.8	92.9
CaO	-635.1	-604.0	39.75
CO_2	-393.50	-394.36	213.64

Table 2 Data from "Thermochemical Data of Pure Substances" [60]

Substance	$\triangle_f H_m$(J·K^{-1}mol)	$\triangle_f G_m$(J·K^{-1}mol)	S_m (J·K^{-1}mol)	$C_{m,p}$ (J·$K^{-1}$$mol^{-2}$)
H_2O	-241.82	-228.59	188.72	33.58
O_2	0	0	205.03	29.36
O	247.52	230.09	160.95	21.91
H_2	0	0	130.59	28.84

and $2nO_2$ is a constant, $nO+2nO_2=4.96\times10^{18}$ mol, so $nO_3\leq1.401\times10^{-23}\times\left(2.48\times10^{18}\right)^2=8.61\times10^{13}mol$.

Result 3): While the current measured value of nO_3 is 6.8×10^{13}mol, just fits our result. (If compress to 1atm at 273.15 K, the thickness will be 0.3 cm).The thermal decomposition in the impact may be the origin of ozone layer.

5 Cyber-simulation by EQS4WIN

The simulation will adopt EQS4WIN, programmed by Mathtrek group. The authors put hundreds of possible atmospheric components and all possible chemical changes into the program. Then the authors put into the temperature, air pressure and other parameters of ancient atmosphere got from the calculation above, and compared the result with the predicted value.

Data chosen were measured by experiments in high temperature from "Thermochemical Data of Pure Substances" [60], as Table 3, and were converted to data under 4 000 K using formula

$$\Delta rHmT=\Delta rHm^{\Theta}+\int_{298.15}^{T}\Delta,$$

$$\Delta rSmT=\Delta rSm^{\Theta}+\int_{298.15}^{T}\frac{\Delta Cp}{T}dT.$$

Other data were computed from the data at 298 K.

According to $\Delta G=\Delta H-T\Delta S$, the authors input the Gibbs free energies at 4 000 K, the temperature, the air pressure and the components of the atmosphere before the impact.

The result of the simulation indicated the genesis of pure O_2 and the escape of H_2. Here are the components of the atmosphere (influenced area) after the impact: O_2: 5.83×10^{18} mol; O: 1.26×10^{18} mol; NH_3: 1.97×10^{14} mol; O_3 : 7.24×10^{13} mol;

The result of the simulation also indicated a preservation of pure oxygen. The hydrogen would escape at 4 000 K. The diffusion velocity of hydrogen is extremely fast. At 1 300 K, the average velocity of hydrogen will reach 5 000 m/s. Furthermore, the cyber-simulation

Table 3 Data used in simulation [60]

Gas	T	Cp	S	-(G-H298)/T	H	H-H298	G	ΔHf	ΔGf	logKf
	K		J/mol.K				KJ/mol			
HNO3(g)	2200	103.858	431.700	353.608	37.498	171.804	-912.243	-124.275	316.752	-7.521
H2O2(g)	1500	68.328	324.479	276.547	64.207	71.899	-550.926	-141.095	27.556	-0.960
HNCO(g)	3000	80.148	388.922	324.469	91.687	193.358	-1075.079	-108.350	8.697	-0.151
CH2	3000	57.182	298.575	253.610	521.285	134.893	-374.439	372.243	237.633	-4.138
CH4(g)	2000	94.420	305.811	44.614	48.721	123.594	-562.901	-92.504	130.940	-3.420
NH(g)	3000	38.006	255.185	224.711	467.980	91.420	-297.574	377.252	316.373	-5.509
NH2(g)	3000	58.186	294.543	251.231	320.311	129.939	-563.320	185.213	310.595	-5.408
NH3(g)	3000	78.938	322.414	264.104	128.990	174.931	-838.251	-50.477	295.630	-5.147
C2O(g)	3000	66.520	362.742	308.586	453.511	162.468	-634.715	283.899	-72.747	1.267
N2H4(g)	1600	111.109	376.890	304.768	210.581	115.395	-392.443	89.594	456.214	-14.894
OH(g)	4000	37.885	267.561	235.827	165.926	126.939	-904.320	33.136	-17.091	0.223
H2O(g)	4000	58.033	303.009	257.121	-58.275	183.551	-1270.309	-254.501	-18.821	0.246
CH2O(g)	3000	79.575	355.258	294.189	67.307	183.208	-998.467	-130.742	-8.703	0.152
CH	3000	41.382	260.645	227.920	692.302	98.174	-89.633	587.629	262.472	-4.570
CaO(g)	3500	63.514	323.429	278.956	199.587	155.655	-932.415	-106.647	-5.915	0.088
CaCO3	1200	130.541	244.634	159.075	-1104.25	102.671	-1397.811	-1203.73	-901.388	39.236
NO(g)	3000	37.469	288.170	256.512	185.266	94.975	-679.245	89.902	52.427	-0.913
NO2(g)	3000	57.584	354.995	306.912	177.343	144.248	-887.642	32.972	221.723	-3.861
N2O(g)	3000	61.693	341.441	290.480	234.928	152.880	-789.393	93.207	296.259	-5.158
N2O3(g)	3000	103.028	515.557	429.415	341.269	258.426	-1205.401	101.534	635.635	-11.067
N2O4(g)	3000	131.781	564.457	454.865	337.856	328.717	-1355.515	49.114	863.214	-15.030
N2O5(g)	3000	148.705	655.749	528.036	394.436	383.139	-1572.810	56.688	1023.610	-17.823
NO3(g)	3000	82.414	418.193	348.716	279.558	208.430	-975.019	86.180	512.037	-8.915
CN(g)398	3000	42.010	280.343	247.930	532.373	97.237	-308.655	425.713	137.462	-2.393
CN2(g)399	3000	61.807	353.329	300.779	630.441	157.649	-429.596	477.423	370.551	-6.452

indicated that lots of the hydrogen would decompose and become free radicals. But at such an extreme condition, the Gibbs free energy of the reaction $N_2 + 6H = 2 NH_3$ reached -1 252 700 J/mol, which meant the reaction will continue until the last molecular. (The O_2 couldn't oxidate N_2 at the same condition.)

According to Berner and Canfield [25] and Falkowski[26], around 600 Ma, O_2 concentration suddenly increased and reached the current level already. The result indicated that life is not the main reason of atmospheric change. This mode is hard to be explained by any other hypothesis.

6 Conclusions

Large amount of evidences supported such a hypothesis:

In Late Precambrian, a celestial body impacted the Earth. The impact solved many problems and was supported by a large amount of evidences. The high temperature ended the great glaciation, facilitated the communication of biological information. The rapid changes of Earth environment enkindled the genesis-control system, and released the HSP-90 variations. After the impact, benefited from the protection of the new ozone layer and the energy supplement of the aerobic respiration, those survived underground life exploded. They generated carapaces and complex metabolism to adjust to the new circumstance of high temperature and high pressure. Maybe one of those swing arms has an abnormal gravitational origin. That's the reason of the impact. The hypothesis may be the solution to the puzzles of the Early Cambrian.

The authors did chemical calculation on the variation of atmospheric components. And the hypothesis is in accordance with the result of computer simulation.

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