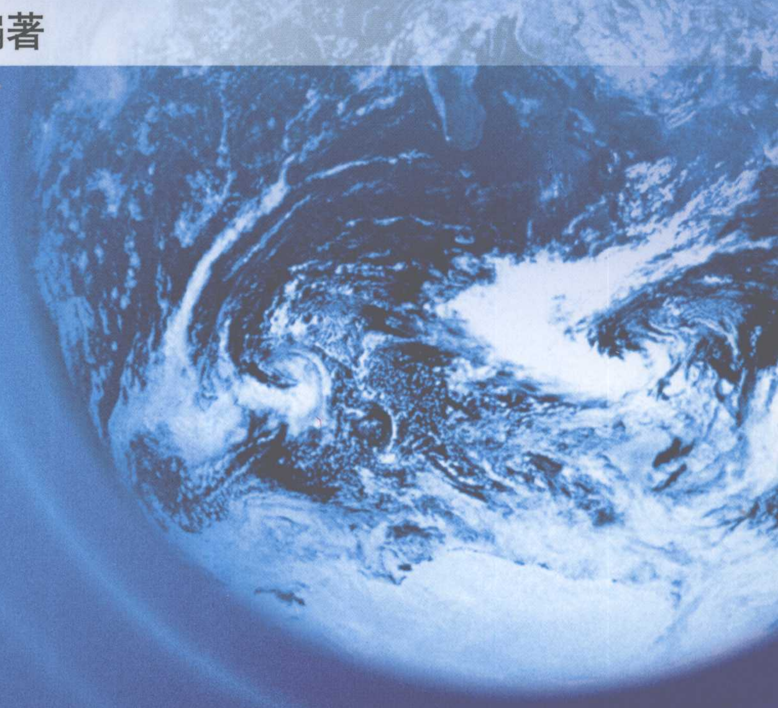
高等学校“十一五”规划教材

# 地球科学专业英语

# English for Earth Sciences

张翼翼　万晓樵　等　编著



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# 地球科学专业英语

# English for Earth Sciences

张翼翼　万晓樵　葛文胜 刘 伟　肖 楠 编著

地 质 出 版 社

·北 京·

## 内 容 提 要

本书以地球科学领域的前缘问题为基础，致力于培养学生对专业英语文献的理解能力，认识本专业的热点问题；通过典型例句的分析，了解地学类文章的特定表述方式；课后有笔译和写作练习，使学生们掌握科技文章的写作策略等。

本书具有较高的实用性和参考价值，适合于高等院校地球科学类专业的学生及相关专业人员参考使用。

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# 前　言

随着我国地球科学的发展，国际间的交流与合作日趋频繁，对国外成果的借鉴日益增多，针对非英语专业硕士研究生的专业英语教学业已成为培养高层次学术交流人才的重要环节。教学实践证明，具有多年基础英语的学习经历尚不能满足实际应用要求。与时俱进的英语教材和动态的教学方法是帮助学生追踪地球科学研究领域全球化步伐的手段和平台。

目前，国内许多院校均不同程度地开设地学类的专业英语课程，但使用的教材在形式上不够规范，内容上不够系统，教学方法因此受到限制。《地球科学专业英语》有效地改变了这一状况，脱离了“作坊式”简易教材的阶段，是中国地质大学（北京）自1989年较早在国内开展地学领域专业英语教学以来，地球科学专业教师和英语教师首度精诚合作的结果。根据中国地质大学(北京)、清华大学和北京大学等五所高等院校的问卷调查，编者做了详尽的分析和总结，经过多次试用修正，力求使教材满足教与学双方的最新期望，符合英语语言和地学专业两方面的认知特点和规律，具有较强的实用性和参考价值，适合全日制高等院校研究生及相关专业人员使用。

本教材以地球科学领域的前缘问题为基础，重点涉及基础地质、古全球变化、古气候学、古海洋学、古地理学、大地构造演化、地质灾害、地质资源、地球环境和研究方法等方面，突破以往所采用的地层、岩石、构造等狭义地质学内容，结合了现代地球科学的思想，具有一定的前瞻性。教材内容均选自近年来国外英语重要杂志上的原版文章，分为八个单元，包括精读课文、泛读课文、新书推介、阅读理解、难句分析、段落翻译和实用写作等部分。每单元后还编辑了生词和音标，便于学生查阅。

通过课堂教学，本教材致力于培养学生对专业英语文献的理解能力；通过体验课外练习，认识本专业的热点问题；通过对典型例句的分析，了解地学类文章的特定表述方式。在练习的编排上，力求多样性、实用性。考虑到地学各专业研究生的特点，每单元后安排了笔译和写作练习以及问题解答练

习，以求巩固专业知识并拓展思路，使学生在英语环境中认识地球科学，熟练操控专业词汇，提高专业文献的阅读能力，掌握英语科技文章的写作策略，最终能够撰写本专业文章的英文摘要，并希望通过大量阅读和持久的写作实践，达到流利阅读和顺畅书写的目的。

《地球科学专业英语》在编写过程中得到中国地质大学（北京）研究生院、地球科学与资源学院和外语系的支持与帮助，并获得研究生院教材基金资助。清华大学外语系何福胜教授和中国地质大学（北京）地球科学与资源学院阴家润教授对初稿进行了审阅，在此一并表示感谢。

万晓樵　张翼翼

2007 年春节

# Contents

# Unit 1

# Paleoceanography

## Learning Objectives

1. Grasp the central argumentation and the structure of the text;
2. Master the key language points and grammatical structures in the text;
3. Learn the writing skill of exemplification in scientific writing;
4. Conduct a series of reading and writing activities related to the theme of the unit.

## Warming-up Exercises

1. What do you know about paleoceanography?
2. What can be credible and effective data to study paleoceanography?

[1] The marriage of modern oceanography with paleoceanography was consummated with the initiation of the Deep Sea Drilling Project (DSDP) and flourished under the successor International Ocean Drilling Program (ODP). The oceans comprise nearly 70% of the Earth's surface, yet as drilling of the ocean crust and overlying sediments progressed under DSDP and ODP, it became evident that the oldest ocean crust, in a few areas such as the northeast Pacific, was only of Late Jurassic age about 160 Ma. The emergence of new oceanic crust at oceanic spreading centres is balanced by the eventual destruction of this crust down subduction zones. Movement of ocean floor is typically of the order of 5—10 cm/yr.

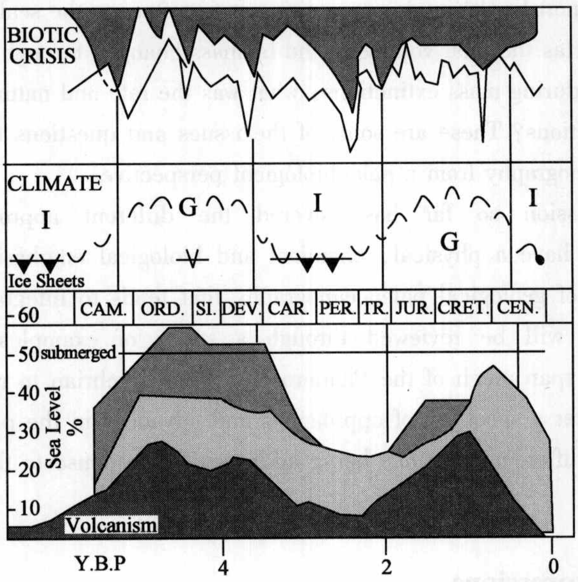
[2] The tools and modes of analysis that the DSDP and ODP cores provided to earth scientists have allowed intense, and typically well integrated studies of the sediments and crust. Detailed work in stratigraphy, sedimentology, paleontology especially micropaleontology, geochronology, geochemistry, paleomagnetism, physical and geotechnical properties have all contributed to a burgeoning database on paleoceanography extending back to the mid-Mesozoic. From a careful repositioning of the continents and the construction of precise paleogeographic maps for this last 200 Ma of Earth history, it has been possible to model ocean circulation and extrapolate ancient climates. Further back in time, the interpretations are less precise and the exercise of reconstructing the ancient paleogeography and paleoceanography becomes a challenge of securing similar data not only from the cores but from sedimentary rocks and crust that now remain on the cratons, on the margins, or which have been abducted or accreted to the continental margins. This record of past ocean rocks is therefore incomplete and the manner of undertaking paleoceanographic research is significantly different prior to and after the mid-

Mesozoic interval.

[3] Despite this almost bimodal approach to paleoceanographic research, a strong common thread is the information provided by isotope proxy signals. Oxygen isotopes reveal information on ancient temperatures of seawater. By analysing, for example, the carbonate tests of both benthic and planktic foraminifera, it is possible to determine the different temperatures of surface and deep ocean waters under which the hard tissue was secreted. Carbon isotopes can determine the changing rates of organic productivity in the biosphere and large excursions can be synchronous with major oceanographic events or with periods of mass extinction. Strontium isotopes reflect changes in the relative flux from only two sources: riverine input from the continents and oceanic hydrothermal venting from the mantle; they reveal the broad pattern of continental erosion and major changes in ocean ridge or plume/superplume activity. As such, strontium isotopes can interpret fundamental tectonic and erosional processes and rates; they are also valuable as a method of correlation for those periods where the curve is changing as it does for the Cenozoic in response to riverine input from newly uplifted mountain chains such as the Himalayas, Alps, Andes, and Cordillera. Neodymium isotopes, with a residence time shorter than the mixing time for the world's oceans, can be used to discriminate different ocean water masses. Neodymium is introduced from continental crust through rivers to the oceans, and today's Atlantic Ocean has different neodymium values than the Pacific due to the contrasting older continental crust and younger volcanic arc sources, respectively. Cerium values can be a useful indicator of periods of anoxia, while boron values are sensitive to changes in salinity. These are some of the main isotope proxy tools that are available to interpret the nature of ancient oceans and are increasingly powerful when used in combination and when extensive sampling is undertaken to yield precise temporal and spatial variations. Most need to be sampled in ways that can provide complementary paleontological and/or geochronological data to ensure temporal resolution. These isotope proxies and other geochemical data collected systematically through more than the last billion years of Earth history represent the heart and appendices of this volume and are covered in more detail in the papers that follow. Together, they are analogous to much of the data gathered in chemical oceanography.

[4] Despite our diminishing knowledge of precise paleogeography back in time, some of the isotope signatures noted above, along with other methods, allow ancient reconstructions through a series of time slices. Of particular importance is the pattern of complete continental assembly during the late Proterozoic and Permian which resulted in a single major ocean on Earth. The broad effects of these supercycles has been addressed by Fischer in terms of paleogeography, volcanism, climate states, and biotic extinctions. Global reconstructions through time enable some speculation as to the pattern of surface and deep-ocean circulation. With more control, particularly post-mid-Mesozoic, improvements over the last decade in developing global circulation models (GCMs) now allow modelling of ancient ocean circulation systems. Such work is comparable to that in physical oceanography. In that field, coupled models are now being developed to link the ocean and atmosphere and eventually to include other system components

such as ice, clouds, and vegetation effects.




Pattern of Phanerozoic supercycles showing the changes in volcanism, sea level, climate state and biotic crisis. I = interglalier; G = glalier

[5] The biotic component of ancient rocks can reveal much data on the nature of the former marine environment. Different associations of organisms are evident along environmental clines and the resulting patterns in ecological hierarchy in community, provinces, and realms are usually strongly indicative of substrate and water mass conditions. Analysis of benthic, nektobenthic and planktonic components of the biota can differentiate spatial variability or stratification of water masses. Taxa may be specialized to indicate differences in salinity (in estuarine or evaporitic environments). The skeletons of most marine faunas were secreted in chemical equilibrium with the surrounding water mass and many of the proxy isotope signals referred to above are derived from the analysis of such skeletal materials. Tracked through time, marine life can be seen to become more complex, diverse, ecologically partitioned, and possibly more abundant in total biomass. The evolution of life is perturbed by radiations, innovations and mass extinctions and the controls or principal forcing agents are not at all clear. Periods when the world's oceans may have been stratified, or more ventilated, or more anoxic can be reflected in responses of the biota. Periods of increased circulation or terrestrial input may enhance total primary productivity, sometimes to the point of creating widespread black shale deposition and anoxia at depth. Again, such studies are analogous to those in biological oceanography. New advances in the latter are demonstrating the complexity of so-called primitive viruses and bacteria, of the deep penetration of the microbiota to hundreds of meters into fractures and pores in the deep ocean crust, of the possible role of such deep microorganisms in geochemical and diagenetic processes in the upper crust. Fundamental questions remain, such as the variability and rate of nutrient supply through time, of changes from superoligotrophic to eutrophic oceans through time, of calcitic vs.

aragonitic oceans that influence chemical composition of carbonate skeletons and the susceptibility of the substrate to support hardground communities or to influence the scale of tiering in the water column or substrate. Has the total volume of the biomass changed through time; how much of the biomass was removed during mass extinctions; what was the rate and nature of the recovery of the biota after mass extinctions? These are some of the issues and questions that are currently being addressed in paleoceanography from a paleobiological perspective.

[6] The discussion so far has covered the different approaches and issues in paleoceanography that have a physical, chemical and biological emphasis. The component not covered so far is that of geological paleoceanography that tends to integrate some parts of these three fields and that will be reviewed through a series of examples of recent studies in paleoceanography that span much of the Phanerozoic, from Cambrian to recent. These examples are intended just to offer a spectrum of approaches and advances in the paleoceanography and to give a glimpse of the different questions being addressed in response to the temporal changes in the Earth systems.

## New words and expressions

### Part A

consummate [ˈkɔnsʌmeit] *v.* make complete or perfect 使完整，使圆满

burgeon [ˈbɜːdʒ(ə)n] *v.* begin to grow rapidly, flourish 开始迅速成长，茂盛

extrapolate [iksˈtræpəleit] *v.* to infer or estimate by extending or projecting known information 推断

secrete [siˈkriːt] *v.* put or keep in a secret place; hide 隐藏，藏匿

synchronous [ˈsiŋkrənəs] *adj.* having identical period and phase 同时期的，同阶段的

appendix [əˈpendiks] *n.* (pl. appendices) section that gives extra information at the end of a book or document 附录

analogous [əˈnæləgəs] *adj.* partially similar or parallel; offering an analogy 类似的，相似的

biotic [baiˈɔtik] *adj.* of or having to do with life or living organisms 生命的，生物的

ventilate [ˈventileit] *v.* cause air to enter and move freely through 使空气进入，使空气流通

ventilation [ventiˈleiʃən] *n.* ventilating or being ventilated 空气流通

equilibrium [ˌiːkwiˈlibriəm] *n.* state of being balanced 平衡，均势

perturb [pəˈtəːb] *v.* to disturb greatly; make uneasy or anxious 使非常烦恼；使不安

speculation [ˌspekjuˈleiʃən] *n.* reasoning based on inconclusive evidence 推测；思考

### Part B

| | |
|---|---|
| oceanography [ˌəuʃiəˈnɔgrəfi] *n.* | 海洋学 |
| paleoceanography [ˌpeiliəuʃiəˈnɔgrəfi] *n.* | 古海洋学 |
| Deep Sea Drilling Project (DSDP) | 深海钻探计划 |

| | |
|---|---|
| Ocean Drilling Project (ODP) | 大洋钻探计划 |
| Jurassic [dʒuəˈræsik] *n.* | 侏罗纪，侏罗系 |
| subduction zone | 消减带，俯冲带 |
| sediment [ˈsedimənt] *n.* | 沉积物，沉积 |
| stratigraphy [strəˈtigrəfi] *n.* | 地层学 |
| sedimentology [sedimənˈtɔlədʒi] *n.* | 沉积学 |
| paleontology [ˌpælionˈtɔlədʒi] *n.* | 古生物学 |
| paleontological [ˌpælionˈtɔlədʒikəl] *adj.* | 古生物学的 |
| micropaleontology [ˈmaikrəʊˌpælionˈtɔlədʒi] *n.* | 微体古生物学 |
| geochronology [ˌdʒi(ː)əukrəˈnɔlədʒi] *n.* | 地球年代学 |
| geochronological [ˌdʒi(ː)əukrəˈnɔlədʒikəl] *adj.* | 地球年代学的 |
| geochemistry [ˌdʒi(ː)əuˈkemistri] *n.* | 地球化学 |
| paleomagnetism [ˌpæliəuˈmægniˌtizəm] *n.* | 古地磁学 |
| geotechnical [ˈdʒiːəʊteknikəl] *adj.* | 土工的，地质技术的 |
| abduct [æbˈdʌkt] *v.* | 仰冲，使外展 |
| accrete [æˈkriːt] *v.* | 增生，增长 |
| Mesozoic [ˌmesəuˈzəuik] *n.* | 中生代 |
| paleogeography [ˌpæliəʊdʒiˈɔgrəfi] *n.* | 古地理学 |
| sedimentary rock | 沉积岩 |
| craton [ˈkreitɔn] *n.* | 克拉通，稳定地块，古陆块 |
| bimodal [baiˈməudl] *adj.* | 双峰的，两形的 |
| isotope [ˈaisəutəup] *n.* | 同位素 |
| proxy [ˈprɔksi] *n.* | (原子或离子) 代替，替代指标 |
| benthic [ˈbenθik] *adj.* | 底栖的，深海底的 |
| planktic [ˈplæŋktik] *adj.* | 浮游的 |
| foraminifera [fəˌræmiˈnifərə] *n.* | 有孔虫类 |
| Carbon isotope | 碳同位素 |
| biosphere [ˈbaiəsfiə] *n.* | 生物圈，生物层 |
| Strontium [ˈstrɔnʃiəm] *n.* | 锶 |
| riverine [ˈrivərain] *adj.* | 河流的，沿河岸的 |
| hydrothermal [ˈhaidrəuˈθəːməl] *adj.* | 热水的 |
| vent [vent] *v.* | 排放，*n.* 火山口 |
| mantle [ˈmæntl] *n.* | 地幔 |
| plume [pluːm] *n.* | 羽毛，羽毛材料 |
| plume structure | 羽状构造 |
| Cenozoic [ˌsiːnəˈzəuik] *n.* | 新生代 |
| Neodymium [ni(ː)əˈdimiəm] *n.* | 钕 |
| Cerium [ˈsiəriəm] *n.* | 铈 |
| anoxia [æˈnɔksiə] *n.* | 缺氧，缺氧症 |

| | |
|---|---|
| anoxic [æ'nɔksik] *adj.* | 缺氧的 |
| boron ['bɔːrən] *n.* | 硼 |
| salinity [sə'liniti] *n.* | 盐分 |
| chemical oceanography | 化学海洋学 |
| Proterozoic [ˌprɔtərə'zəuik] *n.* | 元古宙 |
| Permian ['pəːmiən] *n.* | 二叠纪 |
| supercycle ['sjuːpəˌsaikl] *n.* | 超旋回，超周期 |
| physical oceanography | 物理海洋学 |
| Phanerozoic [ˌfænərə'zəuik] *n.* | 显生宙 |
| volcanism ['vɔlkənizəm] *n.* | 火山作用 |
| cline [klain] *n.* | 渐变群；生态群 |
| substrate ['sʌbstreit] *n.* | 基质：动植物生长或附着的表面 |
| nektobenthic [ˌnektə'benθik] *adj.* | 游泳底栖生物的 |
| planktonic ['plæŋkt(ə)nik] *adj.* | 浮游生物的 |
| biota [bai'əutə] *n.* | 生物群 |
| stratification [ˌstrætifi'keiʃən] *n.* | 层化，成层 |
| taxon ['tæksɔn] *n.* (pl. taxa) | （生物）分类单元 |
| estuarine ['estjuːərin] *adj.* | 河口湾的，三角湾的，港湾的 |
| evaporitic [i'væpəˌraitik] *adj.* | 蒸发盐的；蒸发岩的 |
| biomass ['baiəumæs] *n.* | 生物量，生命体，生物质 |
| terrestrial [ti'restiəl] *adj.* | 地球的，陆地的，陆生的 |
| shale [ʃeil] *n.* | 页岩，泥板岩 |
| deposition [ˌdepə'ziʃən] *n.* | 沉积作用；沉积物 |
| microbiota [ˌmaikrəʊbai'əutə] *n.* | 微生物群 |
| diagenetic ['daiədʒi'netik] *adj.* | 成岩作用的 |
| superoligotrophic ['sjuːpəˌɔlig'trɔfik] *adj.* | 超贫营养的 |
| aragonitic [ə'rægənitik] *adj.* | 文石的 |
| eutrophic [ju'trɔfik] *adj.* | 富营养的，富养分的 |
| calcitic ['kælsaitik] *adj.* | 方解石的 |
| susceptibility [səˌseptə'biliti] *n.* | 灵敏度，磁化率 |
| hardground ['hɑːdˌgraʊnd] *n.* | 硬底，无沉积底，基岩底 |
| paleobiological [ˌpæliəʊbai'ɔlədʒikəl] *adj.* | 古生物学的 |

## Notes to the text

1. The oceans comprise nearly 70% of the Earth's surface, yet as drilling of the ocean crust and overlying sediments progressed under DSDP and ODP, it became evident that the oldest ocean crust, in a few areas such as the northeast Pacific, was only of Late Jurassic age about 160 Ma. (Para. 1)

**结构分析**：该句句子较长，抓住其中的连接词——yet，as，其结构就很清楚了。句子的后半部分是由 it 作形式主语，后面的 that 从句是真正主语。

**译文**：海洋占地球表面积的70%，然而，随着深海钻探计划和大洋钻探计划对大洋地壳及其表面沉积物的钻探，清楚地证实，在某些地区（如太平洋的东北地区）最古老洋壳的年龄只是距今约1亿6千万年的晚侏罗世。

2. Detailed work in stratigraphy, sedimentology, paleontology especially micropaleontology, geochronology, geochemistry, paleomagnetism, physical and geotechnical properties have all contributed to a burgeoning database on paleoceanography extending back to the mid-Mesozoic. (Para. 2)

**结构分析**：句子的主语是 detailed work，由介词 in 引起一连串的名词作为限制语；谓语动词是 have contributed，on paleoceanograph 是 database 的后置定语；extending back to the mid-Mesozoic 是分词作定语，修饰限定 paleoceanography；contribute to“有利于，有助于”。

**译文**：在地层学、沉积学、古生物学，尤其是微体古生物学、地质年代学、地球化学、古地磁学、物理和地质技术等方面的细致研究都有助于形成早至中生代中期以来的古海洋学日益丰富的资料库。

3. Further back in time, the interpretations are less precise and the exercise of reconstructing the ancient paleogeography and paleoceanography becomes a challenge of securing similar data not only from the cores but from sedimentary rocks and crust that now remain on the cratons, on the margins, or which have been abducted or accreted to the continental margins. (Para. 2)

**结构分析**：全句由第一个 and 连接成一个并列句。前半句由 futher … less 这样的比较结构构成“越……越……”的句式；后半句主干部分比较明显——the exercise becomes a challenge，其中第一个 of 引起 the exercise 的后置定语，第二个 of 引起 challenge 的后置定语。not only from the cores but from sedimentary rocks and crust 是 data 的后置定语；that now remain on the cratons, on the margins 和 which have been abducted or accreted to the continental margins 是并列定语从句，修饰 sedimentary rocks and crust。

**译文**：越往前追溯，这种解释就越不准确，重建古地理学和古海洋学也就成了确保来自地核和沉积岩及地壳类似数据准确的一种挑战，这些沉积岩和地壳有的依然存在于克拉通（稳定地块）或地块边缘，有些甚至已经仰冲或增生到大陆边缘。

4. Of particular importance is the pattern of complete continental assembly during the late Proterozoic and Permian which resulted in a single major ocean on Earth. (Para. 4)

**结构分析**：倒装句式。句子的主语是 the pattern of complete continental assembly；of particular importance 是系动词 is 的表语。由于主语带有的修饰语较长——一个是由 during 引起的时间限定语，一个是 which 引导的定语从句，为了避免句子头重脚轻而进行了倒装。be of importance 相当于 be important，这一句式可以推广到其他的不可数名词，如 be of use，be of value 等。

**译文：**在元古宙晚期和二叠纪出现的大陆完全拼合的格局是尤其重要的，这种格局造成了地球上一个完整的海洋。

5. Fundamental questions remain, such as the variability and rate of nutrient supply through time, of changes from superoligotrophic to eutrophic oceans through time, of calcitic vs. aragonitic oceans that influence chemical composition of carbonate skeletons and the susceptibility of the substrate to support hardground communities or to influence the scale of tiering in the water column or substrate. (Para. 5)

**结构分析：**主句结构比较简单，主语是 fundamental questions，谓语是不及物动词 remain，后面由 such as 引起事例说明，其中中心词是 variability and rate，介词 of 带着三个后置修饰语；句子的后半部分还有 that 引起的定语从句来修饰 variability and rate。

**译文：**基本问题依然存在，例如自始至终营养供给的变化和速率、从超贫营养海到富营养海的转变、从方解石/文石海洋的变化，这些变化将影响碳酸盐骨骼的化学组成和基底磁化率，以保持基底群落或影响水体和基底的分层规模。

## Exercises

**Ⅰ. Please answer the following questions:**

1. Why was the oldest ocean crust only of Late Jurassic age about 160 Ma?

2. How can we use different isotope proxy tools to interpret the nature of ancient oceans?

3. Why we say that further back in time, the interpretations are less precise?

4. Can you briefly illustrate the way of modelling ancient ocean circulation systems?

5. What are the issues and questions that are currently being addressed in paleoceanography from a paleobiological perspective?

6. In the text, the term "mid-Mesozoic" is emphasized, how do you understand the different way to reconstruct the paleoceanography of different models in pre-mid-Mesozoic and post-mid-Mesozoic?

7. What happened at the beginning of Cambrian ocean?

8. Please illustrate the evolution of ancient nutrient fluxes and productivity through the last 650 Ma.

9. What are the phenomena of the Cretaceous greenhouse from world oceans?

10. Please demonstrate the role of oceans in a geological period, as indicated in the supplementary reading material below.

**Ⅱ. Please translate the following paragraph into Chinese.**

Planktonic foraminifera originated from benthic foraminifera in the late Jurassic to the early Cretaceous (that's in the Mesozoic, about 100 million years ago). The first planktonic foraminifera were small, rounded forms ('popcorn'), without ridges, probably with spines. During the Cretaceous, many new species evolved, in many different shapes, with ridges and trangular shapes and so on. Almost all of them became extinct at the end of the Cretaceous, at the time of extinction of the dinosaurs, and only the small, round forms survived. In the early Cenozoic planktonic foraminifera evolved into many new, elaborately shaped forms again. Many of these forms becamse extinct in the later part of the Eocene, between 38 and 33 million years ago, when the Earth went through a period of severe cooling and the ice sheets on Antarctica became established. Once again, the rounded form survived, and for about 10 million years were the dominant forms. Then, in the early Miocene (about 22-23 million years ago), the planktonic foraminifera once again evolved and diversified into many different shapes. Descendants of the Miocene species now populate all the world's oceans. Foraminifera are not very abundant and diverse at high latitudes, and only one species occurs at the highest latitudes, in the Arctic Ocean and around the Antarctic continent.

## Writing strategy

举例说明(Exemplification)

Supporting a topic sentence with examples or illustrations makes a general statement specific and easy to understand. In scientific essay, the writing skill of exemplification is often used to make the opinion or statement easier to understand. When exemplification is applied to writing, two points should be kept in mind.

One is to use good and effective examples. Good and effective examples can bring to the reader's mind vivid pictures, and they are used to animate writing, infusing force and interest into what would otherwise be abstract and dull.

The other is to use enough examples. Sometimes, one example can't illustrate the statement sufficiently or the illustration seems too thin. Therefore, more examples can enrich the argument and provide more evidence to support the arguing.

In this essay, Paragraph 3 is very typical in exemplification. In order to illustrate "isotope proxy signals", the writer lists many isotopes in this paragraph and expounds their reflection on climatic or geological changes.

## Writing practice

1. Here is a main point "Bus drivers in my city have no sense of direction". Decide whether the following examples are effective or not.

1) Bus drivers often spend a lot of time judging a right way to a certain destination.

2) Few people would like to take a taxi.

3) Bus drivers have no special training before they get a license.

4) Roads in my city are very complicated and people would easily get confused.

5) Bus drivers call for instructions in direction when taking a passenger.

6) Bus drivers often get lost in my city.

2. Choose one of the topics below and write a paragraph of about 80 words.

1) Proxies for environmental change.

2) The nation's business seemingly requires a disregard for the environment.
3) Plants contribute to environmental improvement.
4) Health mainly depends on food.

## Supplementary reading material:

## Temporal Changes in Paleoceanography

In the Late Proterozoic, profound changes occurred that included the break-up of the supercontinent Rodinia, geographically extensive glaciations, dramatic isotope excursions of, for example, strontium and carbon Jacobsen and Kaufman, this volume on a scale unprecedented in the Phanerozoic, intervals with high abundance of acritarchs suggesting alternating periods of low and high organic productivity, and the emergence of trace, body and skeletonized fossils. Close to the Precambrian-Cambrian boundary, other dramatic biotic events continue that have been described as the Cambrian Explosion. Extensive biomineralization of soft tissue in many major groups of organisms resulted in diverse skeletonized faunas being preserved in the fossil record. Some new biochemical evidence suggests that the initial radiation of major clades of metazoans began about 1200 Ma rather than about 600 Ma ago. If so, what processes or threshold conditions existed to suppress the abundance, size, and diversity radiation for about 600 Ma from 1200 to 600 Ma? Answers may lie in the chemical nature of these oceans. Martin has argued for superoligotrophic oceans for most of the Early Paleozoic. He considered that the oceans were predominantly stratified and only sluggishly circulating; as a consequence there was limited mixing and transfer of nutrients from the deep ocean to surface waters for utilization by organisms (Fig. 1). If the oxygen and $CO_2$ levels of about 0.2, 2 and 20 times the present atmospheric levels, respectively, for the Cambrian are correct, as interpreted by Berner, then a critical threshold factor for respiration and for ecological expansion would have been the $O_2$ levels in the surface and deeper part of the oceans. The interplay of anoxic waters with surface waters somewhat enriched in oxygen is likely to have been a critical factor in the waves of extinctions evident in Cambrian and early Ordovician rocks. Such encroachment of anoxic waters onto carbonate platforms was considered by Zhuravlev and Wood to cause the mid-Early Cambrian Botomian extinction and later the periods of eutrophication to be characterized by phytoplankton blooms. Using Sr and C isotopes data from the Upper Cambrian, Saltzman et al. argued that catastrophic ocean overturning produced similar periodic, widespread, anoxic conditions. Such pulses may well explain the pattern of trilobite extinctions that were used to define biomere boundaries by Palmer.

Progressive ventilation of the deeper oceans appears to have occurred through the Ordovician and Silurian. Attempts to deduce the pattern of oceanic circulation for intervals throughout these two periods have been made by Wilde and Wilde et al., respectively, using the paleogeographic reconstructions of Scotese and McKerrow. The superoligotrophic conditions of these oceans and the warm greenhouse climate state throughout the Early Paleozoic were only interrupted in the Ashgill and early Llandovery (Late Ordovician—Early Silurian) when a continental glaciation developed across North Africa that was then located near the southern pole. The onset of aggressive

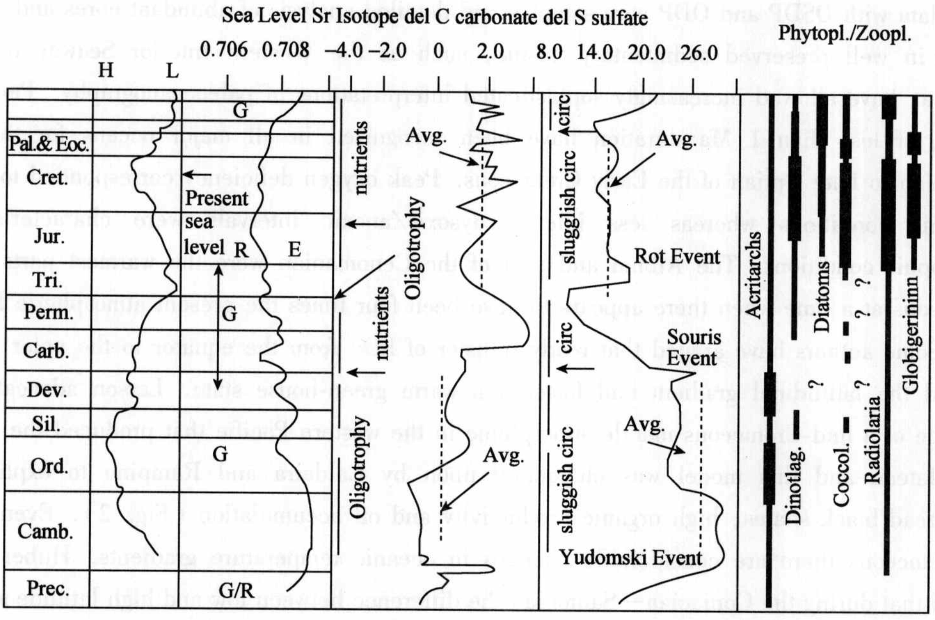



Fig. 1 Indices of ancient nutrient fluxes and productivity through the last 650 Ma

thermohaline circulation both chilled and ventilated the deep ocean with several glacial phases occurring over about a 10 Ma interval, but with the main Hirnantian phase perhaps lasting only for a few hundred thousand years. The cause of this short-lived icehouse state within such a long 200 Ma period of greenhouse conditions is still speculative and some authors have related it to the passage of part of Gondwana over the south polar region or to the brief drawdown of atmospheric $CO_2$. Even as greenhouse states prevailed through much of the Silurian, detailed analysis on conodont microfossil distributions and related microfacies changes have suggested to Jeppsson and Aldridge et al. that the Silurian ocean state and associated climate was characterized by alternating primo and secundo states with periodic, but rapid turnover intervals. The principal differences being a warm humid phase vs. a drier cooler phase that resulted in significantly different lithologies and reef tracts across the low latitude carbonate platforms.

Another seemingly important factor in paleoceanography is the changing pattern of eustasy. Sensitive records are preserved on the carbonate platforms and examination of several cratons allows a global pattern to emerge for the Ordovician and Silurian. Major transgressions produced as epicontinental seas that generated important sites of warm, dense hypersaline waters and the periodic development and then closure of this system with transgressive and then regressive events has not yet been fully accommodated into paleoceanographic models. Such oscillations certainly produced major global bio-events. For the Late Ordovician, the Caradoc transgression was the largest of the Phanerozoic and may have been generated by much higher rates of sea-floor spreading and/or the occurrence of a mantle superplume.

There is a marked contrast in the studies of paleoceanography of the Early Paleozoic with those of the Mesozoic and Cenozoic as noted initially. The application of a wide range of isotope