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中国南方晚古生代介形类的某些集群及其生态探讨

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古生代介形类与沉积环境的关系，是古生代介形类工作者研究的主要课题之一。由于古生代介形类从非海环境到深水海盆均有分布，因此从某种意义上来说，它们在“指相”方面更为重要。在国际上，有关的研究工作，近20年来已取得明显进展，并受到普遍重视。在我国，八十年代以前侧重于古生代介形类的分类描述和在地层划分、对比上的应用，近年来才开始注意这方面工作，并作了一些研究报道（王尚启等，1982，1983；王尚启，1984，1986，1987），但很不系统。笔者的目的是希望通过这篇文章能引起我国古生代介形类工作者的兴趣，共同努力将我国古生代介形类的生态研究引向纵深，为寻找古生代矿床资源提供有效的依据。

在古生代，非海相介形类究竟于何时开始出现，尚无定论，但可靠的化石记录已见于石炭系。在我国，非海相介形类化石最早被报道自晚二叠世龙潭组(阶)(王尚启，1978)；海相介形类化石自奥陶纪(或更早)到二叠纪地层均有发现，且分布十分广泛，为研究古生代介形类与沉积环境之间的关系提供了有利的条件。现以我国南方已发现的晚古生代海相介形类化石为基础，试作集群划分和生态推测。

介形类集群的划分及其生态分析

由于产出的地质时代不同、地理位置不同和岩相不同，介形类化石组合也因此非常庞杂。如何按生态环境将它们归纳成几个集群，在此将作尝试。在集群划分时，本文将力求做到：(1)各个集群要有独自的特色，以便于识别；(2)要有相对较普遍的意义；(3)要有相对较明确的生态范围。根据这些原则，可初步将发现自我国南方晚古生代的介形类化石划分成5个集群(插图1)，并简单介绍如下：

豆石介类集群（leperditiid association）

归入这个集群的介形类组合，主要由壳体大的豆石介类（leperditiids）组成，其余的如瘤石介类（beyrichiids）、卡味尔介类（cavellinids）有时也可见及，但一般属种数量和壳体数量均很少；属种分异度低、密度高和壳面装饰相对较简单。本集群包括两种组合，一种是以壳体巨大（最大可达8cm以上）且十分丰富的似默勒介属（*Paramoelleritia* Wang, 1976）为代表的组合；另一种是以壳体较大（>1cm）且分布成层的豆石介属（*Leperditia*）为代表的组合。前者已先后发现自广西象州和武宣早泥盆世四排组石朋段底部、北流大风门中泥盆世鸭壤段下部和甘肃迭部早泥盆世尕拉组上白云岩段；后者已发现自贵州晚泥盆世桡梭组。这两种组合均产自白云岩或白云质灰岩，化石通常保存较好，其它共生化石很少见及，故推测与潟湖环境密切相关（王尚启，1983）。至于本集群是否会出现在潮间带环境，国外已有记载（Becker, 1971等），我们尚未详细研究。发现自云南曲靖中泥盆世(?)徐冲组底部和下部的豆石介类，一部分保存在白云岩或白云质灰岩中的，可能

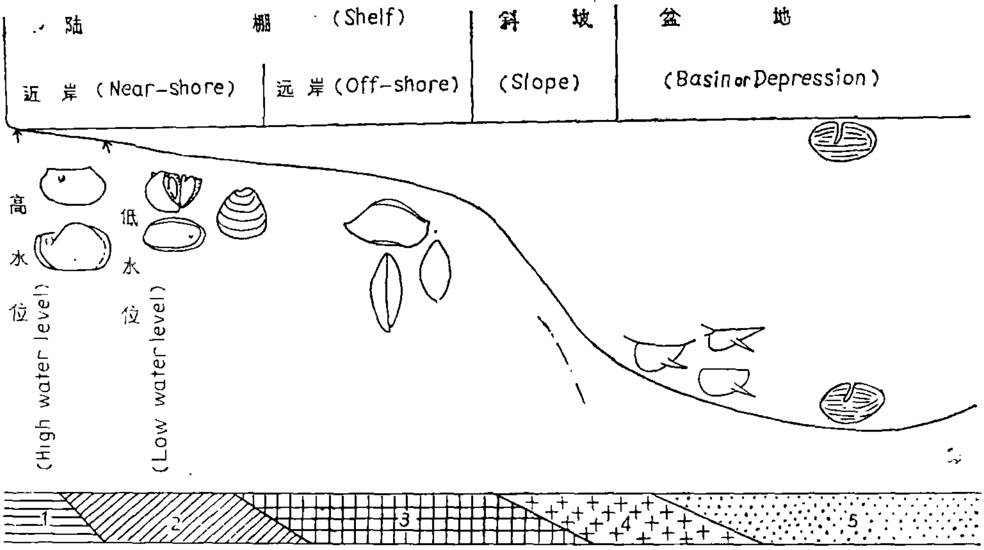

插图 1　中国南方晚古生代某些介形类集群的生态位置示意图
Showing the ecological position of late Paleozoic ostracode associations from South China
1.豆石介类集群 (Leperditiid association)　2.古足目类集群 (Palaeocopid association)　3.光滑速足目类集群 (Smooth-podocopid association)　4.刺状速足目类集群 (Spinose-podocopid association)　5.足虫介类集群 (Entomozoacean association)

与上面分析的一样,与潟湖环境相关;另一部分保存在泥灰岩透镜体内的可能为潮间带环境的产物，因为含泥灰岩透镜体的砂泥岩中发育有交错层理。

豆石介类壳体一般较大且较厚重,背边直,下部较宽,重心低,可能适宜于底栖爬行。由于某些种腹部外突，故也可能在靠近基底作短距离游泳。

古足目类集群 (palaeocopid association)

这个集群的各个组合的主要组成分子是古足目类 (palaeocopids) 和卡味尔介类。它们不仅在属种方面，而且在壳体数量方面均占统治地位。而速足目类 (podocopids), 特别是土菱介类 (bairdiaceans) 通常很少或甚至缺失。这个集群包括存在于广西泥盆纪象州型地层中的大部分组合。由于盛产块状、复体珊瑚等化石，故一般认为象州型地层是在近岸、浅水环境中沉积的。据已掌握的资料,离岸越近、水越浅,介形类属种的分异度越低且密度越高。如产自云南曲靖志留纪关底组、妙高组、玉龙寺组和早泥盆世翠峰山组的介形类组合，主要由属种单调且密度高的瘤石介类、卡味尔介类和隐叶介属 (*Cryptophyllus*) 等组成;广西武宣六峰山早泥盆世郁江组的介形类组合，几乎全由瘤石介类组成。与此相反,介形类属种分异度越高,如产自广西象州和武宣早泥盆世二塘组和四排组石朋段(除盛产似默勒介属的底部外)的介形类组合,通常含有 35 个属种以上。Siveter(1984) 曾分析过 Appalachian Tonoloway Limestone 和 East Baltic basin 的志留纪介形类组合，其结果与我们的推论也相一致。另外，陆源物质的丰富度也影响着介形类的组合，也就是在泥质相中通常以显著装饰的类型为主，如瘤石介类、荷尔介类 (hollinaceans) 和隐叶介属,像在桂东北泥盆纪早圳组中见到的那样 (张康富, 1982)。关于古足目类集群与沉积环境的关系，国外也有过类似的报道,如 Bless (1983) 划分的近岸区中,虽然由于沉积物性质不同,离岸远近不同,介形类组合也因而不相同,但不管如何变化,这些组合却都以古足目类为主。

古足目类是典型的直背类型，其背部较薄、腹部较厚、重心低，适宜底栖爬行；它们常发育有底面支持构造，如镶边、脊、翼等，以防身体陷入淤泥；由于它们腹部常外突，故不能排除在靠近基底处作短距离游泳的可能性。古足目类大部分壳体比较坚实，适于高能地带生活。卡味尔介类的某些有翼的类型，如翼卡味尔介属(*Alatacavellina* Wang, 1983)，可能是营底栖爬行生活的；背部拱、腹部内凹、最厚位于壳体近中部分和壳面光滑的类型，可能营底栖游泳或甚至穴居生活，但也可能生活于水草之上。

光滑速足目类集群 (smooth-podocopid association)

本集群的介形类组合，以光滑速足目类(podocopids)，特别是土菱介类 (bairdiaceans)为主，刺状的速足目类很少，其它常见的还有古足目类的代表，如克尔克贝介类(kirkbyaceans)、似无饰介类 (paraparchitaceans) 和非指纹状的丽足目类 (myodocopids)；壳体普遍较大(>1 mm)。现以产自江苏南通和湖北沔阳晚二叠世长兴期地层的两个介形类组合 (陈德琼、施从广，1982)为例：产自沔阳的速足目类约占总数的72%，其中土菱介类约占速足目类的89%，古足目类 (kirkbyaceans, paraparchitaceans)约占总数的28%，速足目类主要为光滑类型(约82%)；产自南通的，速足目类约占总数的81%，其中土菱介类约占速足目类的82%，古足目类(kirkbyaceans, paraparchitaceans) 约占总数的19%，速足目类以光滑类型为主(68%以上)。另外，两个组合均以较大的个体 (>1mm) 为主。以光滑类型的速足目类，特别是土菱介类为主，伴生有少量刺状或其它装饰的分子和壳体普遍较大，这些特征既不同于盆地型的刺状速足目类集群 (下面将要详细介绍)，又不同于近岸区的古足目类集群，故可能是远岸浅水类型的代表，但不排除有一定幅度的生态扩张的可能性。另外，这个集群通常共生的其它化石是䗴类，而从未发现与块状或复体珊瑚共生，也证明了这个介形类集群主要生活在远岸浅海区。相似于本集群的介形类组合，在国外也通常被视为远岸浅海区的生活类型 (Bless, 1983)，与我们推测的生态位置大致相符。

速足目类，特别是土菱介类，通常背边拱、腹边内凹，背、腹部较薄，近中部分较厚(大致呈流线型外形)和壳面光滑，适宜游泳，故推测它们营底栖游泳生活。它们分布较广，也许是这种生活习性的反映。古足目类，除似无饰介类可能为底栖爬行者外，克尔克贝介类是广相性的，故可能也是营底栖游泳生活的(Dreeson等，1985)。

刺状速足目类集群 (spinose-podocopid association)

在以速足目类为主方面与光滑速足目类集群相似，但不同的是本集群除含有大量土菱介类外，还出现有丰富的且常发育有刺状装饰的类型，如巴尔德金星介类 (bairdiocypridaceans)、浪花介类 (cytheraceans) 等。古足目类(kirkbyaceans, paraparchitaceans)，圆足目类(metacopids: healdiids) 和非指纹状的丽足目类(myodocopids) 等也还是这个集群中的常见分子。另外，壳体普遍小型化 (<1mm)。产自广西南丹巴平早石炭世王佑组的硅化介形类组合(王尚启，1987)就是这个集群的典型一例：速足目类在种和壳体的数量上分别约占总数的81% 和 80%。速足目类包括刺状和光滑两种类型，刺状的有盖罗德介类(gerodiids: *Baschkirina* Rozhd., 1959)，小贝朗介类 (berounellids: *Berounella* Boucek, 1936)。三刺介类 (tricorninids: *Tricornina* Boucek,1936, *Ovornina* Grundel, 1966)，深海浪花介类 (bythocytherids: *Monoceratina* Roth, 1928, *Paraberounella* Blumenstengel, 1965)，某些巴尔德金星介类 (bairdiocypridids: *Praepilatina* Polenova, 1970)，某些厚室介类 (pachydomellids: *Triplacera* Grundel, 1961)，某些土菱介类 (bairdiids) 和 *Rectonaria* Grundel, 1961；光滑类型的有土菱介类 (*Bairdia* McCoy, 1844, *Acratia* Delo,1930, *Fabalicypris* Cooper, 1946, *Bairdiacypris* Bradfield, 1935)，巴尔德金星介类 (*Healdianella* Posner, 1951)，和厚室介类 (*Microcheilinella* Geis, 1933)。刺状种和光滑种分别约占速足目类的 46% 和 54%，但壳体数量前者稍占优势。除速足目类外，还有刺状的圆足目类(healdiids: *Healdia* Roundy, 1926, *Aurigerites* Roundy, 1926)，古足目类 (kirkbyaceans: *Kirkbya* Jones, 1859, *Amphissites* Girty, 1910; paraparchitaceans: *Shishaella* Sohn, 1971) 和丽足目类 [*Discoidella* Croneis et Gale, 1938, *Absina* (*Absina*) Grundel, 1962]。这些介形类壳体通常较小(<1mm)。

前面已经提及，刺状速足目类集群不同于光滑速足目类集群，因此两者所在的古地理环境也就不同。王佑组介形类组合产自瘤状或扁豆状灰岩，并伴生有丰富的牙形刺化石。据我国学者(陈志明等，1983)的意见，广西等地晚泥盆世瘤状或扁豆状灰岩是在台槽环境中沉积的，也就是陆棚较深水环境形成的产物。我们从这个结论中得到启迪：王佑组瘤状或扁豆状灰岩可能是在相似的环境中沉积的。从王佑组介形类组合中的属种来看，个体普遍较小 (<1 mm)、壳壁薄和铰合构造简单或较弱，也可能是在较深水、低能或甚至贫氧环境下的特化现象，像薄壁类型的瓣鳃类那样(王尚启等，1982)。

在国外，刺状的介形类动物群被称为图林根生态型 (Thuringian ecotype)。产自欧洲卡尔尼克阿尔卑斯 (Carnic Alps) 古生代(志留纪到早石炭世)浮游灰岩中的硅化介形类组合就是图林根生态型的典型组合。其与王佑组硅化介形类组合比较如下：

王佑组介形类组合：速足目类约占 81%，古足类目约占 13%，圆足目类约占 3%，丽足目类约占 3%；刺状的或具有其它装饰的约占 56%；壳体普遍较小 (<1mm)。

阿尔卑斯浮游灰岩介形类组合：速足目类占 72%，古足目类占 16%，圆足目类占 5%，其余占 7%；刺状的或具有其它装饰的占70%；壳体多数较小(<1mm)。

从比较的结果来看，前者速足目类比例较大，后者古足目类比例较大；前者刺状或具有其它装饰的类型比例较小，后者较大。究其原因，可能与两地介形类组合产出的地质时代不同有关，因为古足目类主要繁盛在泥盆纪及以前的地质时代，而速足目类则主要繁盛在泥盆纪及以后的地质时代，古足目类一般都具有装饰。

由于具有明显装饰、刺状的介形类动物群与现代冷水圈 (psychrospheric) 的介形类动物群相似，故国外介形类工作者 (Gründel 和 Kozur, 1975) 曾命名它们为冷水型介形类动物群。今天，冷水型介形类动物群主要出现在深海 (>500m) 环境中，但向上也可能在较浅水里发现它们。Olempska (1979) 认为，用今天冷水圈介形类与古生代图林根生态型介形类的相似性来解释图林根生态型的古生境，理由可能是不充分的。Lethiers (1982, 1983) 指出，在泥盆纪和早石炭世期间，图林根生态型的介形类组合曾统治着古赤道附近的海盆。Bless (1983, p. 33) 将图林根生态型的介形类组合划为海盆型，并指出：“晚泥盆世和石炭纪海盆沉积物是在比近岸区和远岸浅水区要深得多的水域里和十分低能的环境下沉积的”。

本集群的介形类壳体普遍较小、壳壁薄和铰合构造发育较弱，像前面已讨论过的那样，是深水、低能环境下的生活类型，包括非刺状装饰类型、刺状装饰类型和光滑类型。非刺状装饰类型，除克尔克贝介类被推测为底栖游泳者 (Dreesen 等，1985)外，其余可能适应于底栖爬行。刺状类型，两侧具有对称侧刺者，主要生活方式可能是底栖游泳，但也不排除行底栖爬行的可能性；具有不对称侧刺者，如 *Praepilatina* 的某些种，其小壳后腹部发育一不大的刺，此刺可能在游泳时使身体平衡 (Bandel und Becker, 1975)。光滑类型，可能包括穴居者，底栖爬行者(如 *Microcheilinella* 的某些种)和底栖游泳者(如许多的土菱介类)。

足虫介类集群 (entomozoacean association)

顾名思义，这一集群包含由足虫介类（entomozoaceans），特别是指纹状的足虫介类（entomozoids）组成的各个组合。关于足虫介类的生活方式，可能主要是营浮游生活的。其理由是：1.从足虫介类本身的构造特征来看，(1)壳壁薄且含钙少，壳面一般具有指纹状构造。前者是使壳体变轻，以适应水面上浮游，然而无抵抗风浪的能力，而后者(指纹状构造)，特别是有横纹构造的，既可增强抵御风浪的能力，又使身体重量不致过多地增加（条纹覆盖面积约为壳面的1/6—1/3，或更小)。(2)两壳等大，无叠覆，两侧对称且常呈流线型。(3)壳体的前端常可见到一凹痕。凹痕的存在，被认为是游泳器官，也就是触角伸出的位置，就像现代的 *Cypridina* 那样(现代浮游介形类的步足一般不发育，而第二对触角发育成游泳器官，与底栖介形类相反)。(4)腹部外突且较薄，有时在腹部发育一向下方伸出的大刺，说明不宜在海底停留。2.从共生化石来看，在晚泥盆世总是与浮游类型的化石共生，如牙形刺、菊石、竹节石等。3.从保存足虫介类组合的岩性来看，说明是在深水、低能和贫氧环境下沉积的(王尚启等，1982)，是不宜底栖生物生存的。4.从足虫介类的地理分布来看，绝大部分属、种都是世界性分布的，也支持了足虫介类是营浮游生活的论点。

浮游生物在海域中分布通常是十分广泛的。足虫介类也应有相似的分布特点。由于足虫介类壳壁薄、含钙低，故很难在高能地带保存为化石。据我所知，在联邦德国 Saurland 地区中泥盆世近岸环境的沉积物中发现过一个足虫介类的标本[*Entomozoe* (*Richteria*) *fragilis* Römer, 1850)]。在我国南方，虽然足虫介类分布相当广泛，已先后在广西、云南、贵州、湖南、陕西和甘肃等地发现了它们，但仅限于泥盆纪和早石炭世南丹型地层及类似的地层，从未在象州型地层中发现过它们。一般认为，前者是远岸、较深水、低能和贫氧环境下沉积的；后者则在近岸、浅水和高能地带沉积的。

属于足虫介类集群的组合，主要发现于广西等地晚泥盆世和早石炭世南丹型地层，如广西南丹罗富晚泥盆世榴江组和早石炭世同车江组，大新下雷榴江组(王尚启等，1982；王尚启，1984)。通过伴生化石和岩石性质的分析，在这些产地，足虫介类被保存在盆地(陆棚凹陷)环境中(王尚启等，1982；王尚启，1984，1986)。如果说刺状速足目类集群占据着盆地较浅水部分，足虫介类集群则占据着盆地相对较深水部分。在国外，足虫介类组合（相当于本文的集群)称为足虫生态型（entomozoan ecotype)，与相关的介形类组合的分布比较是深水盆地或盆地最深水环境的产物（Bandel und Becker 1975)。据 Bandel 和 Meyer (1975) 的研究，在南 Rhineland，产足虫介类的浮游灰岩至少沉积在500—1000m 深的水里。

足虫介类集群的组合的出现，通常意味着水深超越了底栖介形类能够生存的深度。反之，足虫介类与底栖介形类混合保存，意味着水的深度较小。如广西南丹巴定早石炭世王佑组，*Triplacera* 和 *Richterina* (*Richterina*) Gürich, 1896 保存在一起，很可能代表着盆地较浅水部分。类似的情况还可在广西南丹罗富泥盆纪塘乡组中见到。在罗富地区，塘乡组在整个晚埃姆斯期和艾菲尔期总共接受了大约 277m 含炭质的泥岩沉积。在此组中，除产足虫介类和底栖介形类外，还产有竹节石、菊石、三叶虫、鹦鹉螺、瓣鳃类、腕足类、海百合茎和珊瑚等。在晚古生代，海百合主要生活于0—100m 深的浅海海域。在塘乡组中含有较高的炭质，倘若这些炭质来源于底栖藻类，则也表明当时水的深度是较小的。根据现代热带海的情况来看，藻类繁盛的下限，也就是透光带的下限，大约在90—130m 之间（Reynolds, 1978, p. 149)。总之，种种迹象表明，塘乡组可能是沉积在较浅的水域里的，确切地说，属陆棚凹陷浅水部分。

足虫介类在泥盆纪以前就已出现，但主要繁盛在泥盆纪和早石炭世，特别是晚泥盆世和早石炭世。它们除在中国南方分布较广外，还被发现自欧洲(英国、西班牙、法国、联邦德国、

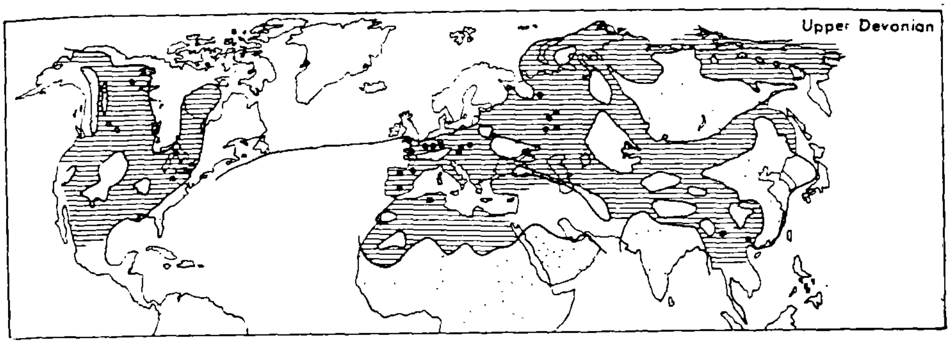

插图 2 晚泥盆世足虫介类世界分布(根据 Groos-Uffenorde, 1984)
Occurrence of Upper Devonian entomozoid ostracodes plotted on the palaeogeographic map of Johnson and Boucot, 1973 (after Groos-Uffenorde, 1984)

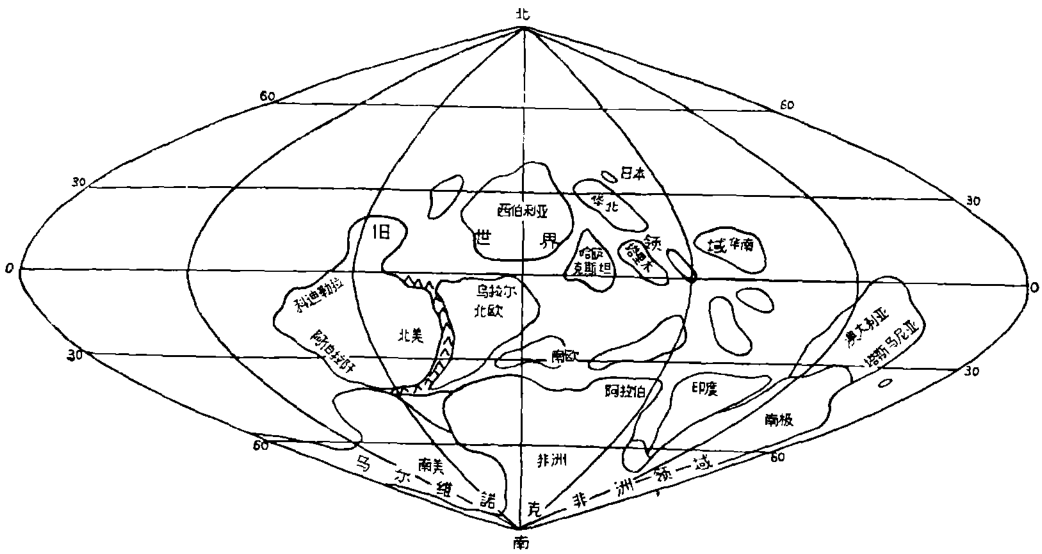

插图 3 泥盆纪世界古地理再造(根据 Heckel 和 Witzke, 1979; 王成源, 1983)
Devonian world reconstruction (after Heckel and Witzke, 1979; Wang Cheng-yuan, 1983)

民主德国、苏联、波兰等)、北美(美国和加拿大)和北非(阿尔及利亚)(插图 2)。根据恢复的泥盆纪世界古地理图(插图 3)可以看出，它们主要分布在古赤道两侧，大约南纬 30°和北纬 30°之间的温暖海域里，与现生丽足目类的地理分布(热带海域)基本一致。至于足虫介类在个别高纬度地带出现的问题，笔者认为有两种可能性：(1) 足虫介类的主要产地是中国南方(广西、滇东南)和欧洲莱茵地区，两者均位于古赤道南北两侧各约 30° 的范围之内，而产自非洲北缘的，据目前所掌握的资料，在属种方面远没有上述两地区丰富，也就是说少量属种也可以在较高纬度地带出现，像现生的丽足目类那样；(2)在泥盆纪，北非的位置不像图 2 上所示的那么高，也就是说可能位于南纬 30°以内，此点还可从产出的珊瑚化石面貌与中国南方的相似得到证明(俞昌民教授口述)。

除上述介绍的 5 个介形类集群外，通常还存在着过渡或混生类型。产自广西象州和武宣早泥盆世四排组丁山岭段的介形类组合主要由古足目类、卡味尔介类和速足目类组成，古足目类和卡味尔介类与速足目类属种的比例大致相

等且优势种均为速足目类，可能属于近岸古足目类集群的组合与远岸浅水光滑速足目类集群的组合之间的过渡或混生类型。其生态位置推测在近岸和远岸浅海区之间。产自西藏聂拉木县亚里组下部的介形类组合(施从广,1982),可能属光滑速足目集群的组合与刺状速足目类集群的组合之间的过渡类型。一方面因为这个组合是由土菱介类、巴尔德金星介类、赫鲁特介类、克尔克贝介类和隐叶介属组成,其中除隐叶介属外,通常见于远岸浅海区到盆地区;另一方面土菱介类只占总数的47%(在光滑速足目类集群中,土菱介类占有的比例要大得多)，刺状的只占速足目类的22%(在刺状速足目类集群中，刺状的和光滑的速足目类之间占有接近相等的比例，如前面已述及的早石炭世王佑组介形类组合)。这一介形类组合可能占据着远岸浅海区到盆地之间的古生境。关于隐叶介属，倘若为优势种，则是近岸环境的标志(Bless 1983, p. 32)，但在本组合中只发现个别标本。

影响介形类集群分布的因素

影响介形类集群分布的因素,一般认为有:盐度、温度、深度、底质和水动力。在盐度方面，除豆石介类集群可能存在于中盐度(mesohaline)或甚至高盐度(hypeısaline)环境外，其余集群一般生活于正常海环境。关于温度，豆石介类集群和古足目类集群，目前主要发现在中国南方泥盆纪地层，根据恢复的泥盆纪世界古地理图(插图2),当时中国南方处于温热气候带;光滑速足目类集群,由于含有大量的土菱介属(*Bairdia*)[此属现代主要产自温暖的陆棚海(Neale, 1984)],故也可能为温暖海域的产物；刺状速足目类集群，据Lethiers(1982, 1983)的意见,在泥盆纪和早石炭世期间,主要围绕古赤道分布。底质情况，除足虫介类集群产自硅、泥质相和碳酸盐相地层外,其余集群一般产自碳酸盐相地层;至于底质的粒度,目前尚未掌握这方面资料。综上所述,看来影响我国南方晚古生代介形类集群分布的因素可能是水的深度、盐度和水动力。

本文划分的5个介形类集群及其相对生态位置的关系,对于早古生代可能也还是有用的,只不过地质时代越老，古足目类在某些集群的组合中占有的比例可能越大。另外，这5个介形类集群，也还可能适用于其它地区。在中国南方以外的地区，尽管在这些集群的组合中会出现这样或那样的变化,但只要产出环境相似,就会出现相应的生态组合。

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LATE PALEOZOIC OSTRACODE ASSOCIATIONS FROM SOUTH CHINA AND THEIR PALEOECOLOGICAL SIGNIFICANCES

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Summary

For the purposes of this paper, an ostracode association is considered to be ostracode assemblages from analogous depositional environments. Based on material from the Late Paleozoic of South China, 5 ostracode associations are proposed, with a discussion on their paleoecological significance.

Ostracode associations and their paleobiotopes

1) Leperditiid association: This association includes those ostracode assemblages dominated by leperditiids, with a low generic and species diversity and a large number of individuals. Other ostracodes (*e. g.* cavellinids, beyrichiids) are often associated with leperditiids, but are very few in the number of genera, species and specimens. Two leperditiid assemblages have been recognized from the Devonian strata of South China: (I) *Paramoelleritia* assemblage, and (II) *Leperditia* assemblage. The first assemblage usually preserved in upper Emsian and Eifelian dolomites or dolomitic limestones is presumably closely related to the lagoonal environments (Wang and Zhang, 1983), while the second assemblage occurring in dolomites or dolomitic limestones of the upper Devonian Raoshu Formation (Shi, 1964) also might have inhabited the same environments. On the other hand, the second assemblage found from the lower part of the Devonian Xichong Formation in Qujing, Yunnan, may be considered as a representative of intertidal environments because of its occurrence in lenticular marls in cross-bedded sandstones interbedded with mudstones. In short, it is possible that this ostracode association

occupied lagoonal and intertidal environments.

2) Palaeocopid association: In this association the predominant ostracodes in genera, species and specimens are palaeocopids and cavellinids, whereas bairdiaceans are rare in genera, though *Healdianella* or *Cytherellina* are relatively common. This association typifies many ostracode assmeblages from the Devonian "Xiangzhou Type" strata, including ostracode assemblages from the Early Devonian Ertang Formation and those from the Shipeng Member of the Early Devonian Szepai Formation (Wang, 1983). It appears that the nearer the shoreline and the shallower the water, the fewer are the forms and the greater is the number of individuals which occur in the assemblages, as seen in the Silurian and Early Devonian strata in the Qujing region of Yunnan. Contrary to that mentioned above, the ostracode assemblages showing an increase in the number of species, such as the aforementioned assemblages from the Ertang Formation and the Shipeng Member of the Szepai Formation, both generally with more than 35 species. In addition, the ostracode assemblages existing in near-shore environments with abundant terrigenous clastic materials are mainly dominated by the heavily ornamented ostracodes (*e.g.* beyrichiaceans, hollinaceans, *Cryptophyllus*), as seen in the Devonian Hanzhen Formation of northeast Guangxi (Zhang, 1982). This ostracode association occurs together with fascicular corals, massive corals, etc., supposedly dominating the shallow water near-shore biotopes (inner shelf) at least during the Devonian.

3) Smooth-podocopid association: In this association, podocopids, especially bairdiaceans, are predominant ostracodes among which smooth species occur in much larger numbers than those with spinose or other ornaments. Among other ostracodes, kirkbyaceans and paraparchitaceans, for example, are common, sometimes also with the occurrence of non-fingerprint types of myodocopids. In addition, most of the ostracode carapaces are larger than 1 mm. Two latest Permian ostracode assemblages, from Nantong of Jiangsu and Mianyang of Hubei respectively (Chen and Shi, 1982), are typical examples of this association, which can be described as follows:

The Mianyang assemblage comprises 39 species characterized by the predominant presence of podocopids (28 species = about 72%) and bairdiaceans (25 species = about 64%), with a minor amount of palaeocopids including kirkbyaceans, paraparchitaceans and others (11 species = about 28%). Podocopids consist mainly of smooth species (= nearly 82% of the podocopid species). The Nantong assemblage contains 42 species and is dominated by podocopids with 34 species (= about 81%), including 28 species of bairdiaceans (= about 82% of the total podocopid species), and some other ostracodes, such as kirkbyaceans and paraparchitaceans, totally with 8 species (= about 19%), while smooth species account for about 68% of the total podocopid species. Another distinctive characteristic of these two assemblages lies in their carapaces which are generally large in size (>1 mm).

This association resembles neither the palaeocopid association from shallow water near-shore environments nor the spinose-podocopid association from "basin" environments (see section 4 below), usually associated with solitary corals, fusulinids, etc. Thus it might have mainly inhabited shallow water but in off-shore (or outer shelf) regions, more likely representing somewhat deeper water rather than shallow water near-shore regions. The possibility can not be ruled out that this association extended into regions with slightly deeper or shallower water than off-shore areas.

4) Spinose-podocopid association: This ostracode association is similar to the smooth-podocopid association in having predominant podocopids, but differs from the latter in the abundance of spinose and other well-ornamented forms such as cytheraceans and certain bairdiocypridaceans, etc., groups which occur together with another podocopid group, bairdiaceans. Palaeocopids (kirkbyaceans, paraparchitaceans), metacopids (healdiids) and myodocopids (non-fingerprint) are also common. Generally, ostracodes in this association are relatively small (<1 mm) and thin-shelled, with relatively weak hingement. A typical example of this association is the ostracode as-

semblage from the Early Carboniferous Wangyou Formation in Baping, Nandan of Guangxi, which can be preliminarily discussed as follows:

This ostracode assemblage comprising 63 species and 2 subspecies, is dominated by podocopids both in species (54 = about 81% of the total species) and in specimens (80% of the total specimens), including spinose forms (24 species = about 46% of the total podocopid species), such as gerodiids (*Baschkirina*), berounellids (*Berounella*), tricorninids (*Tricornina, Ovornina*), bythocytherids (*Monoceratina, Paraberounella*), together with certain pachydomellids (*Triplacera*), bairdiids (*Bairdia* sp. nov., *Bairdiella,* and a new genus), bairdiocypridids (*Praepilatina*) and *Rectonaria*. Smooth podocopids also occur (28 species = about 54% of the total podocopid species) such as pachydomellids (microcheilinella), bairdiocypridids (*Healdianella*), bairdiids (mostly species of *Bairdia, Acratia, Bairdiacypris* and *Fabalicypris*), together with the occurrences of healdiids (*Healdia, Aurigerites*), of the Metacopida, kirkbyaceans (*Kirkbya, Amphissites*) of the Palaeocopida and *Discoidella* and *Absina* (*Absina*) of the Myodocopida, all of which are spinose or heavily ornamented. Both of them and the podocopids with spines and other forms of ornament account for about 56% of the total species in this assemblage. Small (<1 mm) and thin-shelled species with weak hingement are predominant, in contrast to the association with large (>1 mm), thick shells and strong hingement from the shallow marine environment. Therefore, it is reasonable to compare the Early Carboniferous ostracode assemblage from Baping, Nandan with that of the typical "Thuringian ecotype" from the Palaeozoic pelagic limestones of the Carnic Alps (Silurian to Lower Carboniferous), except that the proportion between spinose or distinctly ornamented forms and smooth forms from Baping is a little lower (56%) than that from the Carnic Alps (70%) since the older the strata, the more the palaeocopids (mostly possessing well-developed ornament) are contained in the ostracode assemblages.

The Baping ostracode assemblage (spinose-podocopid association) is preserved in nodular limestones, which, in general, might be deposited in depressions (basins) within the widespread shelf platform in South China. Perhaps small and thin-shelled species with weak hingement were adaptable to an environment with (considerably) deeper water than the normal shelf region, under very low energy and even poor oxygen conditions.

5) Entomozoacean association: This association, as the term suggests, consists of entomozoaceans, particularly entomozoids with "fingerprint" ornamentation (pelagic). Several assemblages belonging to this association have been found from the Givetian to the Early Carboniferous "Nandan Type" strata in Guangxi, Guizhou, etc., especially from the Late Devonian to the Early Carboniferous "Nandan Type" strata in Guangxi. According to lithological characteristics and other associated fossils (conodonts, tentaculitids, ammonoids, etc.), these ostracode assemblages might have been preserved in deeper water depressions (or deeper water parts of depressions) than those occupied by the spinose-podocopid association or ostracode assemblages of the "Thuringian ecotype" within the widespread shelf platform in South China. In general, mixed entomozoid-benthic ostracode assemblages are regarded as indicative of somewhat shallower water depressions than those containing solely the entomozoacean association. A typical example is the "Nandan Type" Tangxiang Formation (upper Emsian to Eifelian), composed mainly of carbonaceous shales, in Luofu, Nandan of Guangxi. On the one hand, the middle and upper parts of the Tangxiang Formation contain both benthic ostracodes and entomozoids, together with tentaculitids, ammonoids, trilobites, nautiloids, bivalves, brachiopods, crinoids, corals, etc., among which the crinoids chiefly inhabited shallow (0—100 m) sea regions during the Late Paleozoic; on the other hand, the Tangxiang Formation also contains abundant carbon possibly originated from algae on the sea floor, and the maximum depth of the abundant algal growth is 90 m—130 m in modern tropical seas (Teichert, 1958). Thus the Tangxiang Formation containing both benthic ostracodes and entomozo-

ids might have been deposited in the shallower water parts of depressions (basins).

Entomozoaceans, especially entomozoids, from the Devonian and Early Carboniferous have been reported from Europe, North America, North Africa, South China (Guangxi, Yunnan, Guizhou, Hunan) and North China (Shanxi, Gansu). Among them, the entomozoids from the upper Devonian are the most widespread in distribution and in low latitudes (approximately between 30° north latitude and south latitude respectively), with a few occurrences (*e. g. Algeria*) possibly in high latitudes (see Text-figs. 2, 3). There are two possibilities to explain those occurring in high latitudes: (I) some of them might have been adaptable to high latitude conditions during the upper Devonian like some modern myodocopids; and (II) the Devonian entomozoids and coral fossils (oral comm. of Yu C. M.) in North Africa appear similar to those of South China and North Africa therefore, might sit in low and not high latitudes at that time (as shown in Text-fig. 3).

In addition to the five associations, mixed associations are also common, particularly those between the palaeocopid association and the smooth-podocopid association and those between the spinose-podocopid association and the entomozoacean association.

Mode of life of the five recognized ostracode associations

Many aspects and methods for determining the mode of life of the Palaeozoic ostracodes have been described by Becker (1975), Siveter (1984), Bless (1985), and others.

Most leperditiids and palaeocopids of the leperdittid association and palaeocopid association were probably benthic crawlers (possibly with many of them occasionally swimming for short distances) because of their straight-backed body with a subtriangular cross-section giving a low center of gravity, and a relatively heavy carapace. This especially applies to palaeocopids with differen forms of basal supporting and defending structures (*e. g.* frills, ridges, spines, etc.). Burrowers might include some cavellinids with smooth carapaces, elongate outline, concave ventral margin and oval cross-section, and also some species of *Healdianella* or *Cytherellina* with pointed anterior ends and an oval cross-section. Most ostracodes of the smooth-podocopid association, especially bairdiaceans, probably could be regarded as benthic swimmers because of their concave ventral margin, oval cross-section, smooth carapace and streamlined outline. Ostracodes of the spinose-podocopid association, as inferred by Becker (1975), might include benthic crawlers, benthic swimmers and even burrowers. However entomozoaceans, particularly entomozoids, were mainly pelagic. It is also possible that many of the abovementioned ostracodes, especially podocopids and metacopids, might swim among or attach themselves to aquatic plants.

Factors controlling the distribution of ostracode associations

In general, salinity and depth together with temperature, substrate conditions and water energy conditions are the main factors controlling the distribution of the recognized ostracode associations.

Salinity: The Late Palaeozoic ostracode associations of South China occur together with corals, brachiopods and other marine organisms. Salinity, therefore, is generally considered to be about normal marine in most of the biotopes, with the exception of the leperditiid association, which might have been adaptable to a variety of possibly brackish to hypersaline conditions (see also Siveter, 1984).

Temperature: Based on fossils occurring in these strata (*e.g.* corals, bairdiids of Ostracoda, etc.), South China was in low latitudes during the Late Paleozoic. Therefore, all of the ostracode associations mentioned above might have inhabited warmer seas.

Substrate: The ostracode associations proposed herein were mainly obtained from carbonate sedimentary rocks. The entomozoacean association, however, was preserved in shales and siliceous rocks, but with no direct relation to the substrate because of the animal's pelagic life-style. So far no study has been made with respect to the sediment grain size, though it is important.

Based on the above-mentioned analysis, it is concluded that depth, salinity and water energy conditions may be the most important controlling factors in the distribution of the Late Palaeozoic ostracode associations from South China.

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