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四川宣汉渡口二叠纪"孤峰组"牙形石序列及其全球对比意义*

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内 容 提 要

渡口"孤峰组"的牙形石带,自下而上包括 *Mesogondolella serrata* 带, *M. aserrata* 带, *M. postserrata* 带, *M. altudaensis* 带, *M. prexuanhanensis* 带和 *M. xuanhanensis* 带。其中前4带可与美国 Texas 州 Guadalupian 统的牙形石带逐个对比。这说明该统 Altuda 组顶部含 *M. altudaensis* 动物群的层位低于吴家坪阶之底;Guadalupian 统和吴家坪阶之间尚存在一个待厘定和命名的新阶。描述了2新种:*M. prexuanhanensis* sp. nov. 和 *M. xuanhanensis* sp. nov.。

关键词　二叠纪　Guadalupian 统　"孤峰组"　Altuda 组　牙形石带

一、前　　言

近几年来,建立二叠系的顶界、底界和系内界线的全球层型剖面和点位(GSSP)的国际合作研究,在国际二叠纪地层分会的推动下,已全面展开。在确定二叠系内部界线方面,研究的重点逐渐转移到建立具有全球对比潜力的统或亚统及其顶界与底界的确切层位,而避免应用涵义不清的上统、中统、下统等非正式地层名称和过多地讨论"二分"、"三分"等方案。

1991年,美国部分二叠系地层工作者总结了多年的工作成果,正式建议将 Guadalupian 统作为二叠系中统的国际标准。该统自下而上包括 Roadian, Wordian 和 Capitanian 3个阶,阶间界线层型剖面选在 Texas 州 Guadalupe 山国家公园西侧陡崖处。Guadalupian 统的下界以 *Mesogondonella serrata* (? = *M. nankingensis*)的初现为标志。虽然 Texas 州西部已发现晚于 Capitanian 阶的沉积,可是上界有待在乐平统的层型剖面上厘定。

在 Texas 州西部,Capitanian 期的盆地边缘相沉积称 Altuda 组。据 Wardlaw(1991)研究,该组自下而上包含 *M. aserrata* 带顶部、*M. postserrata* 带和 *M. sp. nov.* 带。该组的䗴类化石可划分为 *Lantshichites splendens* 带和 *Reichelina lamarensis* 带;后者富集于该组的顶

部，被认为时代晚于 Capitanian 期(Yang Zhendong and Yancey, 1991)。1992 年，Kozur 将 Wardlaw 暂定的 *M. sp. nov.* 命名为 *Clarkina altudaensis*，认为其时代为 Dzhulfian 期或吴家坪期。他还认为 Altuda 组顶部产 *Clarkina subcarinata*，所以该组包含有长兴期早期的沉积。

　　另一方面，国内和国外的二叠纪地层学者普遍认为，世界上 Guadalupian 统以上的二叠纪海相层序以中国南方最为完整。以华南地层剖面为基础建立的乐平统(Lopingian series)已被新编的国际地层表接受(Harland and others, 1990)。由于在乐平世沉积之前曾经发生与一次全球性大海退关联的海生底栖动物的集群灭绝事件，即前乐平统集群灭绝事件(金玉玕，1990)，乐平统与下伏阳新统茅口阶的生物地层和岩石地层界线，粗略地看来是十分显著的。约 90% 的茅口期鏇类和四射珊瑚在这一转变时期消失了；茅口期放射虫、菊石、腕足动物和苔藓虫的优势属种基本灭亡；牙形石的 *Mesogondolella* 属被 *Clarkina* 属代替。然而，对茅口期末期至吴家坪期初期沉积的详细层序至今仍知之甚少。所以，从建立乐平统全球层型剖面的角度来看，目前还难以指出一条具有全球对比潜力的候选界线或地层层位；从了解前乐平统集群灭绝事件的具体过程和成因而论，则缺乏确定全球生物和沉积变化的同时性的高精度地层层序。

　　为了建立茅口期末期至吴家坪期地层的详细层序和寻找可作全球对比的乐平统底界层位，南京地质古生物研究所"二叠纪前乐平统集群灭绝事件"项目组在华南测制了几条茅口期斜坡相沉积剖面(插图 1)。在这些剖面上，这一时期的沉积受茅口期末期全球性海退的影响较少，因而包含较多的化石层。其中之一为四川宣汉渡口剖面。据张继庆、李汝宁等(1990)研究，该地及邻区是"茅口期沉积最完整、吴家坪期最早接受沉积的地区"。在该区，"孤峰组"呈带状展布，沉积于可能与陕南宁强、鄂西北房县、竹溪一带较深水台沟相连的"汉南棚洼"中。

　　初步的分析和研究表明，渡口剖面茅口期沉积不仅含有与美国 Guadalupian 统可对比的牙形石序列，而且还发现比该统最高牙形石带更高、但仍低于华南吴家坪阶最低牙形石带的牙形石动物群。1992 年，Wardlaw 来华共同研究了有关标本，证实和明确了这一牙形石层序。这一事实表明，关于美国 Texas 州 Altuda 组顶部的 *Clarkina altudaensis* 牙形石动物群属于吴家坪期至长兴期的结论是不可取的；而被认为晚于 Capitanian 阶的 Altuda 组顶部至多相当于华南茅口期沉积的顶部，层位低于吴家坪阶之底，两者之间尚有一段地层，其详细层序有待研究和建立。

二、四川宣汉渡口剖面"孤峰组"牙形石分带

　　二叠纪地层分布在渡口附近一箱状背斜的两翼。张继庆、李汝宁等(1990)为研究四川盆地及邻区晚二叠世生物礁，曾详细测制了渡口立石河的"孤峰组"、吴家坪组和长兴组的剖面。综合四川和邻区的一系列剖面，可见渡口一带在二叠纪茅口期至吴家坪期恰处于上扬子
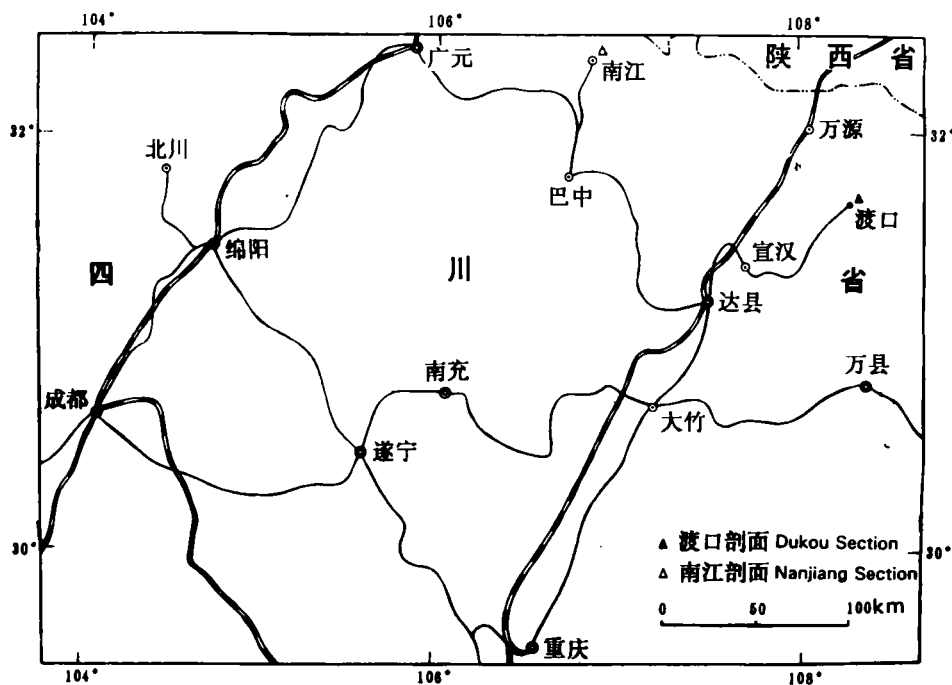
插图 1　剖面位置图
Location of the Dukou and Nanjiang Sections, northeastern Sichuan

陆棚海东北缘的斜坡带,向东北过渡为深水盆地,属于最适合形成完整、连续层序的沉积环境。然而,在渡口立石河剖面上,笔者等见到"孤峰组"与吴家坪组接界处约有10余米厚的岩层被掩盖,在背斜另一翼即观音洞附近,可见其接界处被掩盖约3m厚,并散布着砂岩、页岩碎片,由此推测,"孤峰组"与吴家坪组之间仍有相当王坡页岩的地层存在,因而在岩性上并不是逐渐过渡的。

因开凿公路,张继庆、李汝宁等所作的剖面标记无一留存,故笔者在新开凿的公路剖面上重新作了测量。渡口剖面"孤峰组"厚71.3m,其层序自下而上为:

1. 灰黑色薄层硅质岩与高炭质页岩互层,夹至少6层硅质灰岩,厚18.1m;

2. 灰黑色中至厚层含生屑泥晶灰岩、球粒泥晶灰岩、薄层硅质岩夹紫褐色、紫黑色页岩,厚3.9m;

3. 深灰色薄至中厚层含生屑泥晶灰岩夹黑色薄层硅质岩、燧石条带和结核,燧石由下往上减少,厚12.9m;

4. 深灰色至灰黑色薄层至中厚层生屑泥晶灰岩和含炭质含生屑泥晶灰岩互层,厚30m;

5. 灰色中层扁豆状含生屑泥晶灰岩,中、上部含燧石结核及条带,厚5.2m;

6. 浅灰色厚层角砾状含生屑泥晶灰岩,具柔皱构造,厚1.2m。

笔者对渡口剖面"孤峰组"中、上部以平均间隔0.5m(下部因部分岩性不适合取样,故间隔较厚)、对吴家坪组以平均间隔1m系统采集了牙形石岩样。每块岩样平均重3kg。经分析处理后大多数样品产有丰富的牙形石标本。"孤峰组"牙形石以*Mesogondolella*的种占绝对

优势,此外还有少量的 *Xaniognathus*, *Sweetognathus* 和 *Hindeodus* 的分子,故代表远岸较深水环境的动物群。而且,"孤峰组"牙形石动物群与美国 Texas 州西部 Guadalupian 统的很相似,与 Great Basin 地区相当层位的则明显不同。现主要根据具重要地层意义的 *Mesogondolella* 各个种的地层分布和演化特点,将"孤峰组"划分为 6 个牙形石带(插图 2)。自下而上描述如下:

1. *Mesogondolella serrata* 带

此带分布于剖面上茅口组顶部 0 层至"孤峰组"1 层中上部,包括 3 个含牙形石层位,样号依次为 L-16、17、19。*Mesogondolella aserrata* 在样品 L-19 首次出现,标志着此带的顶界。此带的下界以 *Mesogondolella idahoensis* 演化为 *M. serrata* 为标志,其具体位置尚待追索。

2. *Mesogondolella aserrata* 带

此带包括第 1 层上部至第 4 层下部的 16 个含牙形石层位,依此为 L-19、20、21、22、23、25、26、27.2、28、30、31、33.5、34、36、37、40。此带的底界即为下伏 *M. serrata* 带之顶界。*M. serrata* 未见于 L-20 及其以上的层位。在样品 L-40 已出现高级的 *M. aserrata* 标本。这类标本的齿台后缘直而斜,侧缘呈楔形,但前部横脊仍不发育(图版 I,图 7)。而自样品 L-48 开始,即出现较高级的 *M. postserrata*(图版 I,图 9)。在其间厚 8.1m 的地层中,目前仅发现 L-46.2 产牙形石 *Sweetognathus*。因此,此带虽以 *M. aserrata* 演化为 *M. postserrata* 为顶界标志,然而,其精确位置尚待确定。

3. *Mesogondolella postserrata* 带

此带包括第 4 层中部 7 个牙形石层位,依此为 L-48、52、53、54、55、57、58。此带的底界即为下伏 *M. aserrata* 带之顶界。*M. aserrata* 未见于 L-48 及其以上的层位。上述样品所产 *M. postserrata* 的标本齿台的中后部两侧近平行至微凸,后部略收缩,后缘与外侧缘过渡比该种典型的标本(图版 I,图 14,16,17,20—24)更圆滑,故属于 *M. postserrata* 的高级类型。值得注意的是,此带顶部还含有形态介于 *M. postserrata* 和 *M. altudaensis* 之间、代表前者演化为后者的中间环节的标本(图版 I,图 10,25)。与此类似的部分标本被 Clark 和 Behnken(1979)归入了 *M. babcocki*。*M. altudaensis* 的早期分子(图版 I,图 3—5)在样品 L-58 中首次出现,标志着此带之顶界。

4. *Mesogondolella altudaensis* 带

此带包括第 4 层之中部靠上的 6 个牙形石产出层位,依此为 L-58、59、60、61、63、64。此带之底界即为下伏 *M. postserrata* 带之顶界。*M. postserrata* 在此带下部仍然存在(图版 I,图 10),其后缘向内侧、外侧更圆滑地过渡,后部通常收缩明显,与 Clark 和 Behnken 归入 *M. babcocki* 的标本相似。此带下部产出的 *M. altudaensis* 标本(图版 I,图 3—5)的主齿较明显,近脊沟较深,锯齿较分离,前端发育微弱的横脊。产于上部的 *M. altudaensis* 标本(图版 I,图 1)主齿较小,齿台较平坦,近脊沟较浅,锯齿更融合,前端横脊几乎完全消失。此带顶部(L—61、64)产出的部分标本齿台已变得狭窄,后端收缩明显,齿台侧部表面较凸,锯齿又变得分离,主齿较明显、端生并与齿脊更分离,但大小与锯齿近等,成为 *M. altudaensis* 演化为 *M. prexuanhanensis* sp. nov. 的过渡类型(图版 I,图 6,7,9,15)。*M. prexuanhanensis* sp. nov. 在样品 L-65 中首次出现,标志着此带的顶界。

5. *Mesogondolella prexuanhanensis* 带

此带包括第 4 层上部的 15 个牙形石产出层位,依此为 L-65、68、69.5、71、73、74、75.5、76、77、78.5、79、80、81、82、83。此带的底界即为下伏 *M. altudaensis* 带的顶界; *M. altudaensis* 未见于 L-65 及其以上层位。此带上部(L-76、L-80)产出的 *M. prexuanhanensis* sp. nov. (图版Ⅲ,图 1;图版Ⅱ,图 11)的齿台开始变宽展,齿台侧部渐趋平坦,近脊沟变浅,锯齿更加融合,逐渐向 *M. xuanhanensis* sp. nov. 演化。*M. xuanhanensis* sp. nov. 的早期分子始见于样品 L-86,现作为此带的顶界。

6. *Mesogondolella xuanhanensis* 带

此带包括第 5 层和第 6 层的 19 个牙形石产出层位,依此为 L-86、87、88、88.1、89、90、91、92、93、94、95、96、98.1、99、100、101、102、102.5、103。此带的底界即为下伏 *M. prexuanhanensis* 带的顶界, *M. prexuanhanensis* sp. nov. 在此带的中部(L-95)仍然存在(图版Ⅰ,图 16),但中部的锯齿已经融合。此带下部产出的 *M. xuanhanensis* sp. nov. 的主齿被极窄的齿台后缘包围,较小(如图版Ⅰ,图 2),锯齿融合程度较低,内侧后部凹缺较明显(如图版Ⅰ,图 5);上部产出的 *M. xuanhanensis* sp. nov. 的主齿位于齿台后端,大而明显,锯齿融合成光滑的齿脊,内侧后部凹缺较不发育(如图版Ⅰ,图 14)。

在"孤峰组"之上的王坡页岩中未作牙形石样品的采集和分析;采自吴家坪组的岩石样品经分析获得的牙形石也相当丰富,以 *Clarkina* 的种占绝对优势,同样代表远岸较深水环境的动物群。自下而上可划分出 *Clarkina liangshanensis*?(图版Ⅲ,图 11)带, *Clarkina leveni* (图版Ⅲ,图 12,13)带和 *Clarkina orientalis*(图版Ⅲ,图 15)带,其具体内容拟另文详述。

三、宣汉渡口"孤峰组"牙形石带与美国 Guadalupian 统牙形石带的对比

经过近 40 年的斯巴达克式的艰苦努力,美国学者终于在 Texas 西部建立了完整的 Guadalupian 统牙形石序列(Clark and Behnken, 1979; Wardlaw, 1991, 1992, poster, 29th IGC)。这个序列自下而上包括如下 4 个带: *Mesogondolella serrata* 带、*M. aserrata* 带、*M. postserrata* 带和 *M. n. sp. B* 带。前 3 个牙形石带可与渡口"孤峰组"的逐带对比。如前所述,渡口"孤峰组"的 *M. postserrata* 标本(不对称分子)与产于 Guadalupe 山 Bell Canyon 组 Radar 段下部的标本(Behnken, 1975, 图版 2, 图 32; Clark and Behnken, 1979, 图版 1, 图 13—17)相比,其齿台外侧后缘不如后者平直,并且向外侧缘更圆滑地过渡,显示出更高级的特征,其层位应比后者略高。在我国四川与 Radar 段所产 *M. postserrata* 雷同的标本见于南江剖面(图版Ⅰ,图 14, 16, 17, 20—24)。渡口"孤峰组"的 *M. postserrata* 标本与产于 Lamar 段的标本如图版 2,图 13(Clark and behnken, 1979)难以区分,两者层位应相当。后者被 Clark 和 Behnken 指定为 *M. babcocki* 的模式标本,可见 *M. babcocki* 实际上只代表具高级特征的 *M. postserrata*,可视为后者的后起同义名。Kozur (1992a, 1992b)在与 *M. n. sp. B* 带相同的层位即 Altuda 组顶部采获并命名了 *Clarkina altudaensis*。此种的模式标本的主齿较小,属于 *M. n. sp. B* 的晚期分子。因此, *M. n. sp. B* 带与本文的 *M. altudaensis* 带相当(表1)。
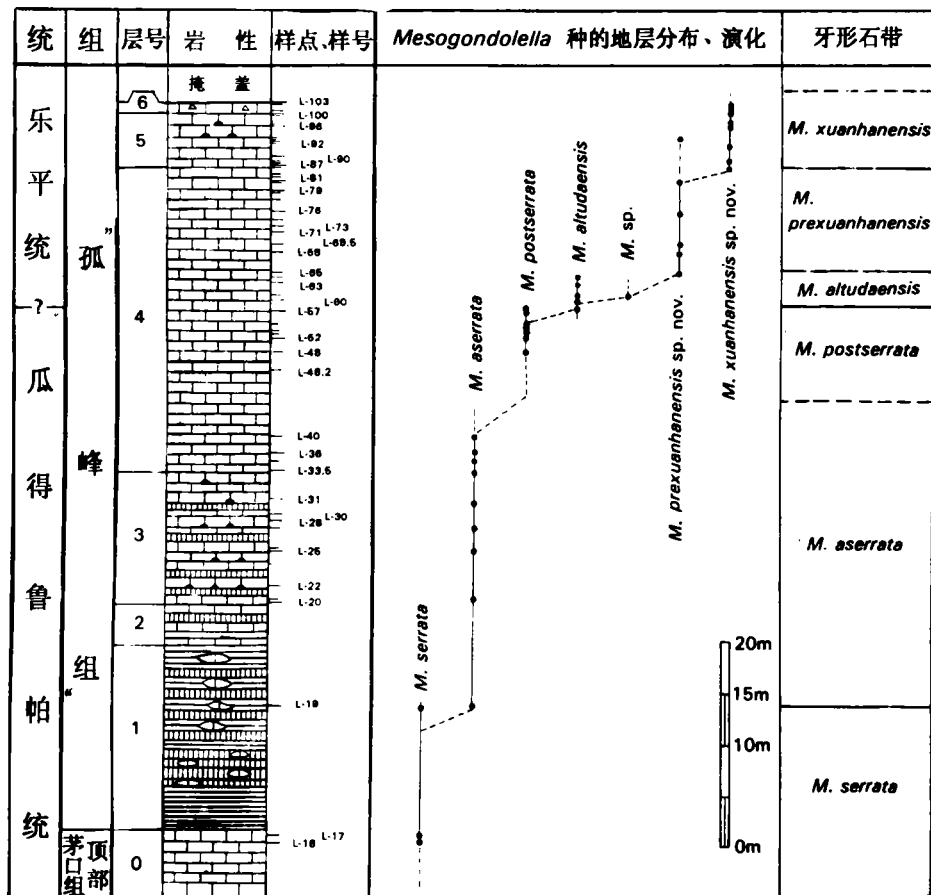
插图 2　四川宣汉渡口"孤峰组"*Mesogondolella* 种的地层分布及谱系演化图

Stratigraphic ranges and phylogenetic evolution of the mesogondolellid conodonts

from the "Kuhfeng" Formation of the Dukou Section, Xuanhan, Sichuan

Clark 和 Behnken(1979)定为 *M. babcocki* 的对称分子的标本(图版 2, 图 14, 15), 其齿台中后部近平行并且向前略收缩, 横脊装饰在齿台前部⅓至½较发育, 显示了比 *M. altudaensis* 更原始的特征, 其层位似应比本文的 *M. altudaensis* 稍低, 而大致与本文 *M. postserrata* 带顶部相当。目前尚未在渡口剖面发现此类对称分子, 但是已在南江剖面 *M. postserrata* 带的顶部见到(图版 Ⅲ, 图 19)。

　　Kozur 采获的 *M. altudaensis* 产于 Old Blue 山西北缘第 2.3 号采石场的 Altuda 组顶部 15m, 自下而上包括层位 148、146、141、143、142、145A、144B、144A、144、140A、139、138。他认为 *M. altudaensis* 产于层位 143 及其以上的全部层位。然而, 就其图版所示的标本而论, *M. altudaensis* 仅产于层位 145A 至 140A, 而产于层位 144 和 140A 的标本(图 5—8, 15, 18)的齿台, 尤其是后端收缩变窄, 齿台侧部表面开始变凸, 锯齿变得较分离, 主齿较明显, 十分接近渡口剖面的 *M. altudaensis* 和 *M. prexuanhanensis* sp. nov. 之间的过渡类型(如图版 Ⅰ, 图 6, 15), 表明已开始向 *M. prexuanhanensis* sp. nov. 演化。Wardlaw(1991)曾在 Kozur 的层位 141 略靠上和层位 142 附近采获了牙形石(Rohr and others, 1991), 经鉴定为 *M. postserrata*; Kozur 图示的产于层位 146 并被他归入 *M. "babcocki"* 的标本(图 4)齿台后缘与外侧缘

过渡较不圆滑，更呈角状，齿台中、前部呈楔形，应为较高级的 *M. postserrata*。在第 2.2 号采石场对面出露的 Altuda 组顶界之下 0.1—0.2m 处，即层位 154，Kozur 采获了定名为 *Clarkina subcarinata* (Sweet, 1973) 的标本 (图 18)。该标本的口面被脏物覆盖，但仍可见主齿很大，并隐约可见齿台前部具横脊装饰，与本文图版 I，图 14 所示的标本相似，很可能属于早期的 *M. prexuanhanensis* sp. nov.。层位 154 距 *M. altudaensis* 最高产出层位 140A 不足 3m，其间并无明显的地层缺失。在特提斯区最早产于吴家坪阶或卓勒法阶顶部的 *C. subcarinata* 不应在 Altuda 组顶部出现，Kozur 的图 18 所示的标本与 *C. subcarinata* 的齿台轮廓的相似很可能是一种异质同形现象。综上所述，Altuda 组顶部大致包含与渡口"孤峰组" *M. postserrata* 带上部至 *M. prexuanhanensis* 带下部相当的牙形石序列，而缺乏与 *M. prexuanhanensis* 带上部和 *M. xuanhanensis* 带相当的牙形石带，两者之对比请参见插图 3 和表 1。

四、论 Guadalupian 统的顶界

由于缺乏可资直接对比的化石序列，目前对美国 Guadalupian 统与特提斯区二叠系的对比意见分歧颇大 (Clark and Wang, 1988；Zhou and others, 1989；Kozur, 1992b；Wardlaw, 1992, poster, 29th IGC)。争论的焦点在于该统上部的 Capitanian 阶是否和特提斯区的吴家坪阶或卓勒法阶在层位上重叠。二叠纪牙形石虽被普遍认为地层对比潜力巨大，但由于其形态变化幅度不大，产出数量较其它地质时期少，目前对其地层分布、生态分布、特别是分类问题的研究还很不够，因而需要耐心细致地积累足够资料 (如系统连续的层序和丰富的标本)并作客观的分析，以避免匆忙从事而使地层问题更趋复杂。1991 年 Kozur 从美国 Texas 州 Altuda 组顶部采获一些牙形石后迅速作了报道 (Kozur, 1992a)，次年他使用 1991 年发表的图版再次报道了他的发现。对照其化石分布表可见，作为该牙形石动物群优势分子的齿台型分子的 7 个种竟有 5 个种的名称作了变动，而对上述化石层位的时代确定也由包含 Dzhulfian 阶变为相当 Dzhulfian 阶和 Changxingian 阶下部，反应出在分类鉴定和地层对比研究中的主观随意性。通过渡口剖面"孤峰组"与 Guadalupian 统的牙形石序列的逐带对比，笔者认为，含上述牙形石动物群即 *M. altudaensis* 动物群的 Altuda 组顶部和吴家坪阶或 Dzhulfian 阶之间不仅没有地层重叠，而且彼此间还至少存在相当于本文 *M. prexuanhanensis* 带上部和 *M. xuanhanensis* 带的一段地层 (表 I)。

既然，Guadalupian 统 Altuda 组顶部的 *M. altudaensis* 牙形石动物群并不属于吴家坪期或 Dzhulfian 期，那么 Kozur (1992a) 提出的以 *M. altudaensis* 首次出现作为 Guadalupian 统的顶界，亦即乐平统的底界的意见能否被接受呢？可能的。实际上这两个牙形石带之间的界线仍不失为一条值得进一步研究的 Guadalupian 统与乐平统的分界。因为在华南吴家坪阶通常以菊石 *Anderssonoceras-Prototoceras* 带，牙形石 *Clarkina liangshanensis* 带的出现为其底界，而含这些化石带的海相地层之下，还有一套经常含煤的碎屑岩相地层，覆于含䗴类 *Metadoliolina* 的茅口期灰岩之上，其时代归属未予详细研究。在渡口剖面上，吴家坪组底部含 *C. liangshanensis*? 带。此带的层位比 *C. liangshanensis* (王志浩，1978) 带低，但吴家坪组与"孤峰组"之间仍夹有相当王坡页岩的碎屑岩层。实际上，这套含煤地层经常被我国地层工作者归入乐平统的底部。
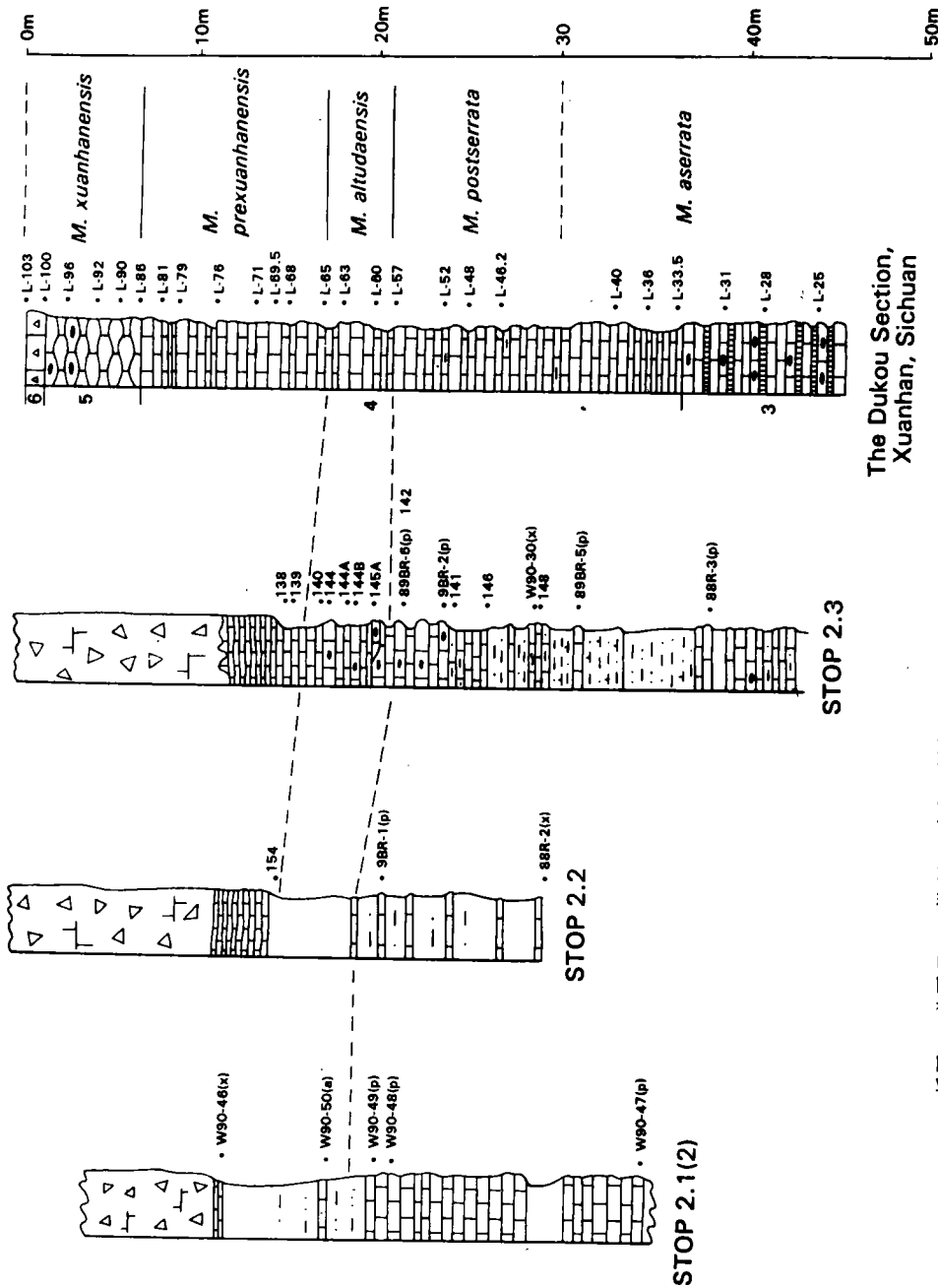
插图 3 美国 Texas 州 Glass 山和四川宣汉渡口的瓜得鲁帕统和乐平统界线地层的柱状图对比图

柱状图观察点 2.1 (2)、观察点 2.2 和观察点 2.3 选自 Rohr 等 (1991)。在柱状图右侧的样号中，138 至 154 为 Kozur (1992a、1992b) 使用的样号，其余为 Wardlaw (1991) 的样号。样号末尾的 (p)、(a) 和 (x) 分别表示该样品含 *M. postserrata*、*M. n. sp.* 和不产肖台型牙形石。

3 Columnar correlation of the strata around the Lopingian/Guadalupian boundary in Glass Mountains, Texas, USA. and Dukou, Xuanhan, Sichuan. The left three columns are adopted from Rohr and others (1991). 138 to 154 are Kozur's collection numbers (1992a, 1992b), and the remaining numbers are Wardlaw's (1991). Collection numbers marked by (a) contain *M. n. sp.*, those marked by (p) contain *M. postserrata*, and those marked by (x) contain no mesogondolellid conodonts.

在伊朗 Abadeh 地区,Taraz(1971)提出,Abadeh 组属于 Guadalupian 统之后、Dzhulfian 期之前的沉积,并据此另建 Abadehian 阶。该组产牙形石 *Merrillina divergens* 和 *Mesogondolella bitteri*,而后者是否为 *Clarkina liangshanensis* 尚存疑问(Bando and others, 1980; Kozur, 1989a)。由于缺乏远海牙形石动物群,Abadehian 阶与 Guadalupian 统的 Altuda 组目前还难以确切对比。Baghbani(1991)在 Abadeh 组上部,即层 4b 发现 *Metadoliolina* 和 *Yabeina*,表明该组也可能相当华南茅口组的最顶部。换言之,Altuda 组顶部有可能与 Abadeh 组约略相当。

表 I　四川宣汉渡口"孤峰组"和吴家坪组牙形石带与美国 Texas 州瓜得鲁帕统的牙形石带对比表

Correlation of conodont zones between the "Kuhfeng" and Wuchiaping Formations of the Dukou Section, Xuanhan, Sichuan and the Guadalupian in Texas, USA.

This paper				WARDLAW 1991, 1992		KOZUR 1992a, 1992b		CLARK AND BEHNKEN 1979
Seri.	Sta.	Fm.	Conodont Zones	Seri	Conodont Zones	Stage	Conodont Fauna	Conodont Zones
LOPINGIAN	Wuchiapingian	Wuchiaping	C. orientalis					
			C. leveni					
			C. liangshanensis ?					
	"Unnamed Stage"	Wangpo Shale						
		"Kuhfeng"	M. xuanhanensis					
			M. prexuanhanensis					
						Dzhulfian and Lower Changhsingian	"C. subcarinata" (No. 154)	
			M. altudaensis	OCHOAN	M. n. sp. B		M. "babcocki" (No. 144)	
							M. altudaensis (No. 145A, 144A, 144, 140A)	
GUADALUPIAN	Capitanian		M. postserrata	GUADALUPIAN	M. postserrata		M. "babcocki" (No. 146) No. 142, 141, 148	M. babcocki
								M. postserrata
	Wordian		M. aserrata		M. aserrata			M. aserrata
	Roadian	Upper Maokou	M. serrata		M. serrata			M. serrata

这样，如果把 *M. altudaensis* 带的底界作为 Guadalupian 统的顶界，势必使乐平统扩充为包括长兴阶、吴家坪阶和一个新的阶。反之，假如不采用这一界线为 Guadalupian 统和乐平统的分界，而将分界上移至吴家坪阶之底部，以 *C. liangshanensis*？的出现为标志，则 Texas 州的 Guadalupian 统却是缺失顶部海相化石层的"中二叠统"，而很难成为国际"中二叠统"的标准。

五、重要属种描述

Mesogondolella Kozur，1988

模式种 *Gondolella bisselli* Clark and Behnken，1971

讨论 Kozur（1988）认为当前属和 *Clarkina* Kozur，1988 的区别是：当前属反口面龙脊呈 V 字型凹，龙脊后端位于反口面后端，基腔位于龙脊后端，缺乏自由齿片；而 *Clarkina* 的反口面龙脊平，边缘常具低的脊，龙脊后端靠近反口面后端，基腔位置靠近龙脊后端，基腔周缘的次生凸起（secondary elevation）较高，前部锯齿高，具明显的自由齿片。就华南所产的有关标本而论，*Mesogondolella* 和早期的 *Clarkina* 在反口面、龙脊和基腔的相对位置这一特征上差别不大。*Clarkina* 的齿台宽阔，中后部一般为近椭圆形，两侧近平行，前部则快速收缩，致使齿台明显分化为中后部和前部两部分；锯齿由前往后明显变低、变小，具高的自由齿片；齿脊窄，其宽度与齿台宽度之比明显小于 *Mesogondolella*，一般为 ⅕ 至 ¼；齿台前部无横脊装饰，但偶尔可见类似横脊的小的波状起伏，然而，这种起伏不规则，在两侧也不成对，与 *Mesogondolella* 的横脊装饰明显不同。*Mesogondolella* 齿台前部和中后部分化不明显，即中、前部通常是均匀地较缓慢地收缩；锯齿由前往后缓慢地变低，中、后部锯齿通常近等高；自由齿片无或很不明显；齿脊较宽，其宽度与齿台宽度之比明显大于 *Clarkina*，一般为 ¼ 至 ⅓；除少数早期分子外，通常或多或少地在前部发育横脊装饰。因此，*Clarkina* 和 *Mesogondolella* 的形态区别显著，分别代表两个不同的齿台型牙形石演化阶段。

Clarkina altudaensis Kozur，1992 无自由齿片，前端具微弱的横脊装饰，齿台中后部和前部分化不明显，齿脊宽度接近齿台宽度的 ⅓，与吴家坪期的 *Clarkina* 各个种具有明显的差别。并且，该种属于 *Mesogondolella serrata* 演化谱系的一个中间环节，其齿体构造与该谱系其他种相似，因此，该种以归入 *Mesogondolella* 为宜。

Mesogondolella altudaensis（Kozur，1992）

（图版 I，1—5）

1992 *Mesogondolella* n. sp. B，Wardlaw，poster 29th IGC．
1992a *Clarkina* cf. *changxingensis*（Wang and Wang），Kozur，pp. 180，181，figs. 9—12，14—17．
1992b *Clarkina altudaensis* Kozur，pp. 103—106，figs. 9—12，14—17．
1992a，1992b *Clarkina* n. sp.，Kozur，fig. 13．
1992c *Mesogondolella* n. sp.，Kozur，fig. 1，Part A，3．
1992c *Clarkina altudaensis* Kozur，fig. 1，Part A，7—9．
1992c *Clarkina liangshanensis*（Wang），Kozur，10．
1992c *Clarkina changxingensis*（Wang and Wang），11．
1992c *Clarkina* n. sp. Kozur，fig. 1，Part B，15．

特征　齿台中等宽度,两侧呈宽弧形,前部内侧微凹,后部内侧略收缩。齿台最大宽度位于齿台后部⅓处或略靠前,自此向后缓慢地收缩,后端钝圆,晚期标本后端变得窄圆;向前较均匀、快速地收缩。齿台轻微至中等程度地向上翻卷,近脊沟中等程度深至浅,早期标本的齿台侧部较晚期标本翻卷强烈,近脊沟更深。齿台前端具微弱的横脊(年轻、早期的标本)或光滑无饰(老年、晚期的标本)。齿脊后部常向内侧弯曲,由12—17个锯齿组成;锯齿在齿台中、后部大部分融合,近等高,在齿台前端略变高,并变得分离。齿台前端无自由齿片。主齿位于近后端,其后具窄的齿台后缘。主齿在早期的标本较大、明显,晚期的标本则较小而不明显。龙脊宽,占反口面约½。齿槽缝状,其后端为 *Mesogondolella* 型基腔。

比较与讨论　在当前材料中,除与此种的模式标本(Kozur,1992b,图9,11)雷同的标本外,还包含此种早期出现的标本,其前端具明显的横脊、较大的主齿。后者曾被 Wardlaw (1992,poster 29th IGC)归入 *M. n. sp. B*。笔者同意 Kozur 关于当前种是由原 *Neogondolella babcocki* Clark and Behnken,1979(即本文所指的晚期出现的 *M. postserrata* 和它与 *M. altudaensis* 的过渡类型)演化而来的。不过,Kozur(1992b)归入 *M.* "*babcocki*" 的部分标本(图5,6)的产出层位处于 *M. altudaensis* 延限范围之上部。这些标本具较大而明显的主齿、更狭窄的齿台、更窄圆的后端、较高凸的齿台侧部、更加分离的锯齿和较发育的横脊装饰,应属 *M. altudaensis* 和 *M. prexuanhanensis* sp. nov. 之间的过渡类型。在渡口剖面"孤峰组"与 Clark 和 Behnken 归入 *N. babcocki* 的标本雷同的标本产于 *M. postserrata* 带顶部至 *M. altudaensis* 带底部;这些标本(图版Ⅰ,图10,25)才代表 *M. postserrata* 和 *M. altudaensis* 之间的过渡类型。

当前种与 *Clarkina changxingensis* (Wang and Wang,1979)的齿台轮廓较相似,但这种相似属于异质同形现象。因为两者具有明显不同的锯齿型式;当前种的锯齿密集,在齿台中后部大部分融合,高度近等,在前部仅稍稍变高,齿脊宽度与齿台宽度之比接近⅓; *C. changxingensis* 的锯齿较分离,并且向后明显变低,齿脊窄,其宽度与齿台宽度之比为⅕至¼。此外, *C. changxingensis* 齿台前部无横脊装饰;而 *M. altudaensis* 前端常具微弱的横脊,收缩更强烈,齿台或多或少地向上翻卷,近脊沟更明显。

当前种通过齿台(尤其是后部)变窄,向上翻卷,后端变得窄圆,主齿变大,并和齿脊更分离,锯齿变得分离,而演化为 *M. prexuanhanensis* sp. nov.。图版Ⅱ,图1、图9、图7、图15、图6、图13、图14 所示的标本依次反应了这一过程。Kozur 归入 *M.* "*babcocki*" 的标本(Kozur,1992b,图5,6)产于 *M. altudaensis* 延限范围之上部,形态与上述过渡分子或 *M. prexuanhanensis* sp. nov. 的早期分子接近,显然也属于 *M. altudaensis* 向 *M. prexuanhanensis* sp. nov. 演化的中间环节。他归入 *Clarkina altudaensis* 的层位较高的标本(Kozur,1992b,图14,15,16),齿台后部已开始明显收缩变窄,与上述过渡类型(如图版Ⅱ,图15)较相似,代表着 *M. altudaensis* 开始向 *M. prexuanhanensis* sp. nov. 演化的较早期阶段。

Kozur (1992b)关于当前种直接演化为 *C. changxingensis* 的推论是一个误解,因为当前种与 *C. changxingensis* 的形态相似属于异质同形现象。此外,在渡口剖面上在当前种和 *C. changxingensis* 产出层位之间隔着"孤峰组"最顶部、王坡页岩和吴家坪组,其中并不存在当前种和 *C. changxingensis* 之间的过渡型分子。

当前种产于渡口剖面"孤峰组"这一事实表明,Kozur (1992b)关于当前种属卓勒法期至

长兴期的推测也是错误的。他将 *M. altudaensis* 定为卓勒法期至长兴期的唯一依据是发现 *Hindeodus julfensis* (Sweet, 1973)(图 20)与之共生。姑且不论 *Hindeodus julfensis* 的定义及地层延限尚有争论,单就其定为 *Hindeodus julfensis* 的标本仅 1 枚(图 20),而且残破不全,有磨损现象,即可说明这一种的鉴定颇为勉强。

产地层位 四川宣汉"孤峰组"*M. altudaensis* 带,美国 Texas 州西部 Altuda 组顶部,Lamar 灰岩顶部。

Mesogondolella postserrata（Behnken, 1975）

（图版 I, 图 8—10, 12, 14—17, 19—25）

1975 *Neogondolella serrata postserrata* Behnken, pp. 307—308, pl. 2, figs. 31, 32, 35.

1979 *Neogondolella postserrata* Behnken, Clark and Behnken, p. 272, pl. 1, figs. 13—17, 21.

1979 *Neogondolella rosenkraitzi* (Bender and Stoppel), Clark and Behnken, pp. 272, 273, pl. 2, figs. 3, 8, 9.

1979 *Neogondolella babcocki* Clark and Behnken, p. 273, pl. 2, figs. 5, 6, 11—15, 17, 18.

1979 *Neogondolella denticulata* Clark and Behnken, p. 272, pl. 1, figs. 18—20, 22, 23.

1980 *Gondolella behnkeni* Bando and others, p. 11.

1984 *Neogondolella babcocki* Clark and Behnken, 张景华等, 图版 2, 图 1, 2.

1984 *Neogondolella aserrata* Clark and Behnken, 张景华等, 图版 2, 图 9。

1988 *Neogondolella postserrata* Behnken, Clark and Wang, figs. 4?, 5?, 6.

1989 *Neogondolella postserrata* Behnken, 李子舜等, 232, 233 页, 图版 40, 图 7—9;图版 50, 图 8, 9;图版 51, 图 14, 15。

1989 *Neogondolella behnkeni* (Kozur), 李子舜等, 264 页, 图版 50, 图 1—5。

1990 *Neogondolella postserrata* Behnken, Jiang, pl. I, figs. 3a, 3b.

1990 *Neogondolella babcocki* Clark and Behnken, Jiang, pl. I, figs. 5a, 5b.

1990 *Neogondolella wilcoxi* Clark and Behnken, Jiang, pl. I, fig. 6; pl. II, figs. 5a, 5b.

1992a, 1992b *Mesogondolella "babcocki"* (Clark and Behnken), Kozur, fig. 4.

比较和讨论 Wardlaw 等 (1990)、Rhor 等 (1991) 将 *N. denticulata* Clark and Behnken, 1979 和 *N. babcocki* Clark and Behnken, 1979 视为当前种的同义名,并且将 Clark 和 Behnken (1979)归入 *N. rosenkrantzi* (Bender and Stoppel)的标本也归入当前种。笔者在渡口、南江等剖面所产的大量的 *M. postserrata* 的标本中也发现与上述被归入 *N. denticulata* 和 *N. rosenkrantzi* 的标本类似的标本(如图版 I, 图 20),其形态与典型的 *M. postserrata* (如图版 I, 图 22)逐渐过渡,故这两个种与当前种的形态差异属种内变异。笔者同时也发现与上述被归入 *N. babcocki* 的标本雷同的标本(如图版 I, 图 10, 19, 25)。这些标本虽然其形态与典型的 *M. postserrata* 连续过渡,但在层位上往往较典型的 *M. postserrata* 和上述被归入其它两种的标本稍高。

Kozur 虽同意 *N. babcocki* Clark and Behnken, 1979 作为当前种的同义名,但认为 Clark 和 Behnken 图示的除指定为正模(图版 2, 图 13)以外的标本的后缘至少在一侧向侧缘圆滑过渡、后端尖或窄圆,应归入一个新种,并暂定为 *Mesogondolella "babcocki"* (Clark and Behnken, 1979)。然而,在 Kozur (1992b)归入该种的标本中,图 4 所示标本的齿台后缘较平直而斜,中前部呈楔形,属较典型的 *M. postserrata*;而图 5, 6 所示的标本应为 *M. altudaensis* 向 *M. prexuanhanensis* sp. nov. 演化的过渡类型。在当前材料中,与被归入 *N. babcocki* 的标本类似的标本(图版 I, 图 10, 19, 25)产于 *M. postserrata* 带顶部,其形态介于 *M. postserrata*

和 *M. altudaensis* 之间,并与两者连续过渡,而且与前者更接近。因材料尚不充分,笔者仍将它们视为最高级的 *M. postserrata*,暂不另建新种。

戴进业和张景华认为, *M. nuchalina* (Dai and Zhang)与当前种的区别是"齿台相对狭长的轮廓及齿台后部具凹缺构造",与 *M. aserrata* 的区别是齿台后部向里收缩和前部具横脊装饰(李子舜等,1989,230—233页)。实际上, *M. postserrata* 的齿台内侧后部常略收缩, *M. aserrata* 的齿台内侧后部也常收缩,而且前部常具微弱的横脊,因此, *M. nuchalina* 的齿台形态介于上述两种之间。此外,他们将在此种最高产出层位亦即其正模产出层位 Gsc3-1 之上的层位 Gcs3-2 获得的标本分别归入了 *N. postserrata*(李子舜等,1989,图版 50,图 8,9), *N. aserrata*(张景华等,1984,图版 2,图 9), *N. behnkeni*(李子舜等,1989,图版 50,图 1—5)和 *N. babcocki*(张景华等,1984,图版 2,图 1,2)。就图版所示的标本分析,归入上述各种的标本齿台后缘直而斜,齿台呈楔形或中后部两侧近平行,与早期的 *M. postserrata* 相似。由此推测,该种的层位比渡口剖面的 *M. postserrata* 低,而且,该种很可能处于 *M. aserrata* 向 *M. postserrata* 演化的过渡阶段。

产地层位　四川宣汉、南江"孤峰组"*M. postserrata* 带,华南茅口组,美国 Capitanian 阶。

Mesogondolella prexuanhanensis Mei and Wardlaw sp. nov.

(图版 I,图 6?,8,10—14,16;图版 II,图 1)

1992b ? *Clarkina subcarinata* (Sweet, 1973), Kozur, p. 107, fig. 18.

种名词源　pre-,拉丁语前缀词,在……之前;xuanhanensis,种名。取出现于 *Mesogondolella xuanhanensis* sp. nov. 以前之意。

特征　齿台狭长,中等程度拱曲,前部常明显向反口方折曲。最大宽度位于齿台后部约 $\frac{1}{3}$ 处略靠前,自此向后收缩变窄,向前较均匀地收缩变窄。齿台后端窄圆,后部内侧通常较外侧收缩明显,致使外侧凸圆,内侧略凹。齿台侧部窄,其宽度通常与齿脊宽度近等。齿台侧部向上中等程度翻卷,与齿脊间形成中等程度深的近脊沟。齿台前部约 $\frac{1}{3}$ 具横脊装饰。齿脊具 14—17 个锯齿,在齿台中后部,锯齿下部融合,上部分离,锯齿向前略变高,在前部变得更加分离。主齿位于齿台后端,通常大而明显,并和齿脊明显分离。龙脊占反口面 $\frac{1}{3}$ 强,扶壁较明显,缺刻通常不明显。齿槽缝状, *Mesogondolella* 型基腔。

比较　当前种与 *M. nuchalina* (Dai and Zhang, 1984)和 *M. postserrata* (Behnken, 1975)的区别是:主齿端生,大而明显,并和齿脊明显分离;齿台更狭长,向后收缩更明显,后端突出;齿台两侧弧形,外侧后缘与侧缘圆滑地过渡,后端窄圆。当前种与 *M. altudaensis* 的区别是:后者齿台较宽阔,后端钝圆,内侧后部收缩不明显;主齿较小,其后方齿台后缘较发育;锯齿较融合。

讨论　Kozur 归入 *Clarkina subcarinata* (Sweet, 1973)的标本(Kozur, 1992b,图 18)的主齿很大,齿台前部隐约可见横脊,与本文的标本图版 I,图 14 相似,很可能属于 *M. prexuanhanensis* sp. nov.,但是该标本的重要特征如锯齿型式,因脏物覆盖,而在直接观察研究该标本之前尚不能确定。

在相当于上述标本(图 18)产出层位之下约 3m, Kozur 采获了归入 *M. "babcocki"* 的标

本(Kozur，1992b，图5，6)，其齿台狭窄，后端窄圆，锯齿较分离，但主齿较小，并与齿脊分离较不明显。它们与当前种的早期分子或过渡分子(图版Ⅱ，图6)形态接近，显然属于 *M. altudaensis* 向 *M. prexuanhanensis* sp. nov. 演化的中间环节。

产地层位 四川宣汉"孤峰组"*M. prexuanhanensis* 带。

Mesogondolella xuanhanensis Mei and Wardlaw sp. nov.
(图版Ⅱ，图2—10，14)

种名词源 以首次发现产地四川宣汉(Xuanhan)命名。

特征 齿台中等程度拱曲，最大宽度位于后部约⅓处。自此向后齿台收缩变窄，并向内侧稍稍弯曲，齿台后端窄圆。齿台后部外侧凸圆，内侧通常收缩成一弧形至近直线形凹缺，凹缺与之前的内侧缘过渡通常不圆滑。齿台中、前部呈楔形，内侧前部常略凹。齿台侧部表面平坦，微向齿脊倾斜，在前部约¼具微弱的横脊。近脊沟位于齿台平面与齿脊相交处，通常很浅或无。齿脊中、前部较直，后部略向内侧弯曲。齿脊由约20个锯齿组成，中、后部的锯齿大部分融合，中部的锯齿常融合成一条脊，晚期标本大部分锯齿通常融合成平滑锋利的纵脊。主齿明显，位于齿台后端，并与齿脊分离。主齿有时与其前一个锯齿融合。反口面微凹，扶壁明显，缺刻不明显至明显。龙脊占反口面⅓强，齿槽缝状，其后端为 *Mesogodolella* 型基腔。

比较 当前种与 *M. nuchalina* (Dai and Zhang，1984)的区别是：前者齿台后端窄圆，并突出；主齿端生，明显，并和齿脊明显分离；齿台后部外侧圆滑，中、前部两侧呈楔形，前部更窄，横脊较不发育。齿台平坦，近脊沟很浅或无，中部的锯齿通常融合成平滑的脊；扶壁明显。*M. nuchalina* 的齿台后部收缩较不明显，最宽处位于齿台近中部；主齿不明显，其后齿台边缘较发育；齿台外侧后缘较平直，与之前的外侧缘过渡不圆滑，即在过渡处齿台外侧较宽，更显得成角状；齿台前部较宽，横脊发育。当前种齿台轮廓与 *M. aserrata* (Clark and Behnken，1979)较相似，但后者齿台较宽，常呈泪滴状，后端宽圆，后部不如当前种收缩强烈；主齿之后具窄的齿台后缘；齿台前部通常较弯曲，而当前种则较直；近脊沟尤其在齿台中部靠前较明显，而当前种齿台侧部平坦，近脊沟不明显；锯齿融合程度高；反口面扶壁不明显。当前种与 *M. prexuanhanensis* sp. nov. 的区别是：后者齿台侧部向上翻，表面凸，两侧呈宽弧状；近脊沟明显，较深；齿脊上锯齿更分离，不融合成平滑的齿脊；齿台前部横脊更发育；后部凹缺较不发育，主齿更大。当前种显然是由 *M. prexuanhanensis* sp. nov. 通过齿台宽展变平、近脊沟相应变浅至消失、锯齿变得更融合、主齿变小、横脊变弱演化而来。

产地层位 四川宣汉"孤峰组"*M. xuanhanensis* 带。

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SUCCESSION OF CONODONT ZONES FROM THE PERMIAN "KUHFENG" FORMATION, XUANHAN, SICHUAN AND ITS IMPLICATION IN GLOBAL CORRELATION

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Summary

The Lopingian marine sequence is fully developed in South China and has potential to serve as an international standard for correlation of the Latest Permian. A conventional lower boundary of the Lopingian Series was placed at the base of *Clarkina liangshanensis-C. bitteri* zone (Wang and Wang, 1979, 1983; Wang, 1990; Ding, 1992) and/or *Prototoceras-Anderssonceras* zone, which represents the first fossiliferous marine bed in the shelf sequence. However, information about the precise succession of marine fossil zones from the Latest Maokouan and the Earliest Lopingian based on which the stratigraphic level of Maokouan (Guadalupian)/Lopingian boundary can be selected is still not available at present. Such a succession can only be found from the sequences of slope deposits or basin deposits because South China seas had been exclusively affected by a major

regression towards the end of Maokouan. As a result of the regression, a terrigenous formation is sandwiched in between the marine deposits of Maokouan and Lopingian on the shelves. Zhang and others (1990) reported that in the Dukou Section, Xuanhan, Sichuan, the marine sequence from Late Maokouan to Early Lopingian is nearly complete as they formed in a Maokouan basin. A closer examination shows there still exists a terrigenous bed, though it is much thinner than the equivalents formed in shelf areas. The overlying Wuchiaping Formation produces numerous conodonts that are dealt with in detail in another paper (in print.). It consists of packstone and wackestone and contains *Clarkina liangshanensis* in the middle part and a conodont zone which is temporarily designated as the *Clarkina liangshanensis* ? Zone in this paper, in the basal part.

The "Kuhfeng" Formation underlying the terrigenous bed comprises thin-bedded limestone with intercalations of chert beds. Based on stratigraphic ranges and phylogenetic evolution of mesogondolellid conodonts from the "Kuhfeng" Formation (Text-fig. 1), six conodont zones are recognized in ascending order, as follows: *Mesogondolella serrata* Zone, *M. aserrata* Zone, *M. postserrata* Zone, *M. altudaensis* Zone, *M. prexuanhanensis* Zone and *M. xuanhanensis* Zone (Text-fig. 2). The first four zones can be correlated one for one with those of the Guadalupian Series in western Texas, the United States (Table I). The latter two zones occurring in the uppermost part of the "Kuhfeng" Formation are stratigraphically higher than the youngest conodont zone of the Guadalupian Series, i. e. the *M. altudaensis* zone. Kozur (1992a, 1992b) considered the *M. altudaensis* Zone, as Dzhulfian to Early Changhsingian in age, but it is apparently lower than the base of the Wuchiapingian (Dzhulfian) Stage of the Lopingian Series conventionally defined loosely by the first appearance of *Clarkina liangshanensis*, and also the *Clarkina liangshanensis*? Zone from the base of the Wuchiaping Formation in the Dukou Section. In case the upper boundary of the Capitanian Guadalupian Series is put in between the *M. postserrata* Zone and the *M. altudaensis* Zone, as proposed by Glenister and others (1990), it is evident that a new stage, representing the time interval from *M. altudaensis* Zone to *C. liangshanensis*? Zone, which is temporally unnamed, should be defined on the succession well documented from the upper part of the Maokouan of China.

The upper 15m of the Altuda Formation at Stops 2. 1(2), 2. 2 and 2. 3 in the Glass Mountains (Rohr and others, 1991) yields a conodont fauna correlated well with that from the upper *M. postserrata* Zone to the lower *M. prexuanhanensis* Zone of the "Kuhfeng" Formation in the Dukou Section as illustrated in Text-fig. 3. The correlation expressed in Table I further indicates that there is no reason to assign the conodont fauna from the upper 15m of the Altuda Formation at Stops 2. 2 and 2. 3 to the Dzhulfian and Early Changhsingian (Kozur, 1992a, 1992b).

The conodonts from the "Kuhfeng", Wuchiaping and Changhsing Formations in the Dukou Section are exclusively dominated by the gondolellids. The systematic problems

about Permian gondolellids urgently need to be clarified and can be on the abundant collections of conodonts from sections with successive conodont zones such as those in South China. Conodonts have proved to be useful in setting up a high-resolution biostratigraphic scheme of the Permian. For these purposes, some of the mesogondolellids obtained from the "Kuhfeng" Formation are redefined or described, and a possible phylogenetic evolutionary lineage of the mesogondolellids from *M. serrata* through *M. aserrata*, *M. postserrata*, *M. altudaensis* and *M. prexuanhanensis* sp. nov. to *M. xuanhanensis* sp. nov. is proposed in this paper (Text-fig. 2).

Mesogondolella Kozur, 1988

Type species: *Gondolella bisselli* Clark and Behnken, 1971

Remarks: According to Kozur (1989), this genus can be distinguished from *Clarkina* Kozur, 1989 by its lacking a free blade, lacking abrupt ending of platform against anterior part, and mostly bearing a serrated anterior margin. The materials dealt with herein show that the ratio of carina's width to platform's width ranges from $\frac{1}{4}$ to $\frac{1}{3}$ for *Mesogondolella*, while in *Clarkina* is less than $\frac{1}{4}$. As the lower surface of platform in advanced forms of *Mesogondolella* is close to that of primitive forms of *Clarkina*, it is not quite important in recognition of these two genera.

Clarkina altudaensis Kozur, 1992, bears commonly weak serrations in its anterior platform, lacks free blade and a distinct abrupt ending of platform against anterior part, with a ratio of carina's width to platforms's width between $\frac{1}{4}$ and $\frac{1}{3}$. All these features indicate that this species should be shifted into the genus *Mesogondolella* and probably representing one of the intermediate links in the *M. serrata* Lineage.

Mesogondolella altudaensis (Kozur, 1992)

(Pl. **I**, figs. 1—5)

1991　　*Mesogondolella* n. sp., Wardlaw, p. 17.

1992a *Clarkina* cf. *changxingensis* (Wang and Wang), Kozur, pp. 180, 181, Figs. 9—12, 14—17.

1992b *Clarkina altudaensis* Kozur, pp. 103—106, figs. 9—12, 14—17.

1992a, 1992b *Clarkina* n. sp., Kozur, fig. 13.

1992c *Mesogondolella* n. sp., Kozur, Fig. 1, Part A, 3.

1992c *Clarkina altudensis* Kozur, Fig. 1, Part A, 7—9.

1992c *Clarkina liangshanensis* (Wang), Kozur, 10.

1992c *Clarkina changxingensis* (Wang and Wang), 11.

1992c *Clarkina* n. sp., Kozur, Fig. 1, Part B, 15.

Diagnosis: Platform moderately broad, and widest around its posterior third, with arc-like lateral margins. Posterior end bluntly rounded, often slightly asymmetrical. Posterior end of carina slightly to strongly deflecting towards inner side. Carina in adult forms with 12—17 considerably fused denticles, which are slightly higher in anterior part of platform,

and almost equally high in middle and posterior parts. Cusp distinct in young specimens and primitive forms, tending to be indistinct in adult specimens and advanced forms, generally surrounded posteriorly by narrow platform brim. Keel flat, occupying about half of the lower surface. Basal cavity subterminal with elevated margins.

Comparison and remarks: The specimens referred to *M.* n. sp. by Wardlaw (1991) are assigned to this species. They are characterized by the bigger cusp and better developed serrations, and appear to represent the early forms of the present species. Wardlaw feels these specimens are transitional from *M. postserrata* to *M. altudaensis*. Kozur (personal commun., 1993) feels serrated forms are *M.* n. sp. of Wardlaw and smooth forms are *M. altudaensis*. We find relict serrations in most of our abundant specimens (even topotypes) of *M. altudaensis* and find no stratigraphic distinction between "smooth" and serrated morphotypes of this short ranging species.

This species resembles *Clarkina changxingensis* (Wang and Wang, 1979) in the platform outline, but can be easily distinguished from the latter by the characters of denticulations and serrations in the anterior platform. In the former, the carina is wider, and the ratio of carina to platform in width ranges from $\frac{1}{4}$ to $\frac{1}{3}$; the denticles are considerably fused and almost equally high in the posterior and middle part of the carina, and become slightly higher and more discrete in the anterior platform; the cusp is surrounded posteriorly by a narrow platform brim, while serrations, although often weakly developed, commonly exist at the anterior end of the platform. In the latter, however, the carina is narrow, and the ratio of carina to platform in width is less than $\frac{1}{4}$, the denticles are compressed laterally but distinctly lower and more discrete posteriorly; the cusp is commonly reclined and terminally located, and there are no serrations in the anterior platform.

This species seems to evolve in a phylomorphogenetic continuum from *M. postserrata* (Behnken, 1975) through the posterior end of platform becoming smooth and bluntly rounded, the lateral margins turning to be arc-like, adcarinal furrows shallowing and denticles tending to be more fused, as shown successively by the specimens illustrated in Pl. I, figs. 12, 8, 10, 25, and Pl. II, figs. 3—4.

We disagree with the conjecture to regard this species as the forerunner of *C. changxingensis* (Kozur, 1992a, 1992b), the evidences from the present collection show that the present species gave rise to *M. prexuanhanensis* sp. nov. in a phylomorphogenetic continuum. The specimens figured in Plate II, figs. 1, 9, 7, 15, 6, 13 and 14 exhibit successively that the platform especially its posterior end tends to become narrower, the lateral platforms are more upturned, the cusp is bigger, terminally located and distinctly set off from the carina, and the denticles are more discrete. The specimens named *M.* "*babcocki*" by Kozur (1992b, figs. 5, 6) from the upper part of the stratigraphic range of *C. altudaensis* are comparable to the specimen shown in Pl. I, fig. 6, and likely represent one of the transitional forms between the present species and *M. prexuanhanensis*. The specimens of *M.*

altudaensis illustrated by Kozur (1992b) in figs. 14—16 already show an extensively narrowed posterior end, and thus indicate the initiation of *M. prexuanhanensis* evolving from *M. altudaensis*.

Occurrence: *M. altudaensis* Zone of the "Kuhfeng" Formation, Xuanhan, Sichuan; Upper Altuda Formation, Uppermost Larmar Limestone, western Texas, USA.

Mesogondolella postserrata (Behnken, 1975)

(Pl. Ⅰ, figs. 8—10, 12, 14—17, 19—25)

1975 *Neogondolella serrata postserrata* Behnken, pp. 307—308, pl. 2, figs. 31, 32, 35.

1979 *Neogondolella postserrata* Behnken, Clark and Behnken, p. 272, pl. 1, figs. 13—17, 21.

1979 *Neogondolella rosenkrantzi* (Bender and Stoppel), Clark and Behnken, pp. 272, 273, pl. 2, figs. 3, 8, 9.

1979 *Neogondolella babcocki* Clark and Behnken, p. 273, pl. 2, figs. 5, 6, 11—15, 17, 18.

1979 *Neogondolella denticulata* Clark and Behnken, p. 272, pl. 1, figs. 18—20, 22, 23.

1980 *Gondolella behnkeni* Bando and others, p. 11.

1984 *Neogondolella babcocki* Clark and Behnken, Zhang and others, pl. 2, figs. 1, 2.

1984 *Neogondolella aserrata* Clark and Behnken, Zhang and others, pl. 2, fig. 9.

1988 *Neogondolella postserrata* Behnken, Clark and Wang, figs. 4?, 5?, 6.

1989 *Neogondolella postserrata* Behnken, Li and others, pp. 232, 233, pl. 40, figs. 7—9; pl. 50, figs. 8, 9; pl. 51, figs. 14, 15.

1989 *Neogondolella behnkeni* (Kozur), Li and others, p. 264, pl. 50, figs. 1—5.

1990 *Neogondolella postserrata* Behnken, Jiang, pl. 1, figs. 3a, 3b.

1990 *Neogondolella babcocki* Clark and Behnken, Jiang, pl. 1, figs. 5a, 5b.

1990 *Neogondolella wilcoxi* Clark and Behnken, Jiang, pl. Ⅰ, fig. 6; pl. Ⅱ, figs. 5a—5b.

1992a, 1992b *Mesogondolella "babcocki"* (Clark and Behnken), Kozur, fig. 4.

Comparison and remarks: *N. babcocki*, *N. denticulata* and *N. rosenkrantzi sensu* Clark and Behnken (1979) were regarded as junior synonyms and morphotypes of *M. postserrata* (Behnken, 1975) by Wardlaw and others (1990) and Rohr and others (1991). Transitional forms between the morphotypes mentioned above and typical forms of *M. postserrata* are also common in the present collection from both the Dukou and Nanjiang Sections. It is observed that specimens similar to those referred to *N. babcocki* by Clark and Behnken (1979) appear in the upper part of the *M. postserrata* Zone, while specimens similar to those referred to *N. denticulata* and *N. rosenkrantzi* by them abound in the lower and middle parts of the *M. postserrata* Zone in both the Dukou and Nanjiang Sections. The specimens shown in Pl. Ⅱ, figs. 10, 19, 25, which are similar to those referred to *N. babcocki* by Clark and Behnken (1979), express transitional characters between *M. postserrata* and *M. altudaensis*, but are more close to the former in morphology. They are here regarded tentatively as the most advanced forms of *M. postserrata*.

The specimen referred to *M. "babcocki"* and illustrated in fig. 4 by Kozur (1992a, 1992b) has a nearly straight and oblique posterior end and a wedge-like and upturned platform, and probably belongs to the somewhat advanced *M. postserrata*.

M. nuchalina (Dai and Zhang, 1984) resembles the primitive forms of both *M.*

postserrata and *M. aserrata*. According to Dai and Zhang (*in* Li and others, 1986), it was distinguished from the present species by the concave posterior part of the inner lateral margin and the narrower platform, and from *M. aserrata* by the distinctly serrated anterior platform. Specimens from Horizon GSC3-2, which is higher than Horizon GSC3-1 producing the holotype of *M. nuchalina* in the Shangsi Section, Guangyuan, Sichuan, were referred to *N. postserrata* (Li and others, 1986, Pl. 50, figs. 8, 9), *N. aserrata* (Zhang and others, 1984, Pl. 2, fig. 9), *N. behnkeni* (Li and others, 1986, Pl. 50, figs. 1—5) and *N. babcocki* (Zhang and others, 1984, Pl. 2, figs. 1, 2) respectively. The majority of these specimens bear a straight and oblique posterior end, a broader anterior platform and well-developed serrations, and likely belong with the primitive *M. postserrata. M. nuchalina*. Probably, they represent the transitional forms in evolution of *M. postserrata* from *M. aserrata* .

Occurrence: *M. postserrata* Zone of the "Kuhfeng" Formation, Xuanhan, Sichuan; Maokouan, South China; Capitanian, USA.

Mesogondolella prexuanhanensis Mei and Wardlaw, sp. nov.

(Pl. Ⅰ, figs. 6?, 8, 10—14, 16; Pl. Ⅱ, fig. 1)

? 1992b *Clarkina subcarinata* (Sweet, 1973), Kozur, p. 107, fig. 18.

Etymology: From the Latin pre-, meaning "before", in reference to the inferred evolutionary relationship to *M. xuanhanensis* sp. nov.

Diagnosis: Platform narrow, moderately arched, with anterior part commonly deflecting aborally, broadest at or a little before posterior third of platform, and tapering posteriorly and anteriorly from the broadest part. Posterior end narrowly rounded, changing into both inner and outer lateral margins smoothly. Posterior part of inner lateral margin slightly concave to straight, and that of outer lateral margin commonly convex. Anterior third of platform with well-developed serrations. Ratio of carina to platform in width around $\frac{1}{3}$. Lateral platform moderately upturned, and adcarinal furrows moderately deep. Carina with 14—17 denticles, which are discrete in their upper part in the middle and posterior parts of the carina and becoming largely discrete in the anterior part. Cusp big, located terminally, often distinctly separated from carina by a small gap. Keel occupying $\frac{1}{3}$ of the lower surface or a little more. Buttress commonly not set off by notches.

Comparison: The present species is distinguished from *M. nuchalina* (Dai and Zhang, 1984) and *M. postserrata* (Behnken, 1975) by its big and terminally located cusp which is distinctly set off from the carina, narrowly rounded posterior end which changes into both lateral margins smoothly, and narrower platform which tapers posteriorly in its posterior third. *M. altudaensis* is different from the present species in its broader and less upturned platform with bluntly rounded posterior end, smaller cusp surrounded by a narrow platform brim, and extensively fused denticles. The present species can be distinguished from *M. xuanhanensis* by its upturned lateral platforms, well-developed adcarinal furrows, less

fused denticles, bigger cusp and less concave posterior part of the inner lateral margin.

Remarks: The specimen figured first as *Clarkina subcarinata* (Sweet, 1973) and later as *Clarkina lanceolata* (Ding) by Kozur (1992a, 1992b, fig. 18) with a big and terminally located cusp is very similar to the specimen illustrated in Pl. I, fig. 14 in the present paper. It probably belongs to *M. prexuanhanensis*, but this can be confirmed only by a restudy of the specimen, because its oral surface is so much covered by matrix that the serrations in the anterior platform are unclear.

Occurrence: *M. prexuanhanensis* Zone of the "Kuhfeng" Formation, Xuanhan, Sichuan.

Mesogondolella xuanhanensis Mei and Wardlaw, sp. nov.

(Pl. I, figs. 2—10, 14)

Etymology: From its occurrence in Xuanhan, Sichuan.

Diagnosis: Platform moderately arched, broadest at its posterior third, and tapering posteriorly and anteriorly from the broadest point. Posterior end narrowly rounded. Posterior part of inner lateral margin concave to straight, while that of outer lateral margin convex. Middle anterior part of inner lateral margin commonly straight, while that of outer lateral margin slightly convex to straight, resulting in the wedge-like middle and anterior parts of the platform. Lateral platform flat; adcarinal furrows very shallow or absent. Anterior fourth of platform weakly serrated. Posterior end of carina slightly deflecting towards inner side. Carina with about 20 strongly fused denticles. Middle carina with denticles often entirely fused into a sharp ridge. Cusp distinct, located terminally, sometimes partly fused with the most posterior denticle. Lower surface slightly concave. Buttress commonly not set off by notches. Keel occupying $\frac{1}{3}$ or a little more of lower surface.

Comparison: This species is distinguishable from *M. nuchalina* (Dai and Zhang, 1984) by its platform widest at posterior third from which it tapers posteriorly, narrowly rounded posterior end which changes into both lateral margins smoothly, flat lateral platforms, absence or very shallow adcarinal furrows, terminally located cusp, strongly fused denticles, less developed serrations and fairly distinct buttress. It is different from *M. aserrata* (Clark and Behnken, 1979) in its narrower platform tapering posteriorly in its posterior part and wedge-like in middle and anterior parts, terminally located cusp, flat lateral platforms, absence or very shallow adcarinal furrows, and distinct buttress.

Remarks: *M. xuanhanensis* appears to evolve in a phylomorphogenetic continuum from *M. prexuanhanensis*. The specimens illustrated in Pl. I, fig. 8, Pl. II, fig. 1, Pl. I, fig. 11 and Plate II, figs. 2, 4 and 5 successively exhibit the upturned lateral platforms tending to become flat, adcarinal furrows accordingly very shallow or absent, denticles strongly fused, the middle carina ridge-like, cusp smaller and serrations less developed.

Occurrence: *M. xuanhanensis* Zone of the "Kuhfeng" Formation, Xuanhan, Sichuan.

图 版 说 明

本文图示的所有照片皆为电镜扫描像片。标本全部保存在中国科学院南京地质古生物研究所。除说明者外,照片皆放大 80 倍,产地皆为四川省宣汉县渡口乡。

图 版 Ⅰ

1—3.18. *Mesogondolella serrata* (Clark and Ethington)

口视.18 为年轻个体,采集号:L-19,L-16,L-19,L-19;登记号:121128—121131。"孤峰组"*M. serrata* 带。

4—7.11.13. *Mesogondolella aserrata* (Clark and Behnken)

口视。采集号:L-31,L-36,L-25,L-40,L-36,L-40;登记号:121132—121137。"孤峰组"*M. aserrata* 带。

8.9.12.14—17.20—24. *Mesogondolella postserrata* (Behnken)

口视。14,16. ×50.17, ×40,20—24, ×50.产地为四川南江桥亭。采集号:L-55,L-48,L-52,Dg-22,L-57,Dg-20,Dg-22,Dg-17,Dg-20,Dg-17,Dg-17,Dg-17;登记号:121138—121149。"孤峰组"*M. postserrata* 带。

10.19.25. *Mesogondolella postserrata* (Behnken)

口视。晚期分子;类似标本被 Clark 和 Behnken 归入 *M. babcocki*,为 *M. postserrata* 和 *M. altudaensis* 之间的过渡类型。19. × 50.四川南江桥亭。采集号: L-58,Dg-22,L-57;登记号:121150—121152。"孤峰组"*M. postserrata* 带顶部。

图 版 Ⅱ

1—5. *Mesogondolella altudaensis* (Kozur)

1a,2b,3,4b,5. 口视;1b,2a,4a 分别为 1a,2a,和 4b 之侧斜视。采集号:L-60,L-59,L-58,L-58,L-58;登记号:121153—121157。"孤峰组"*M. altudaensis* 带。

6.8.10—14.16. *Mesogondolella prexuanhanensis* sp. nov.

6a,8a,10,11b,12b,13a,14a,16b. 口视;6b,8b,11a,12a,13b,14b,16a. 分别为 6a,8a,11b,12b,13a,14a 和 16b 之侧视;16a,16b. X50;6a,6b. 为过渡类型. 主齿小;11a,11b. 为晚期分子,齿台侧部较平坦,代表 *M. prexuanhanensis* sp. nov. 和 *M. xuanhanensis* sp. nov. 之间的过渡类型;12 为 Holotype。采集号:L-64,L-76,L-68,L-80,L-69.5,L-68,L-65,L-95;登记号:121158—121165。"孤峰组"*M. prexuanhanensis* 带。

7.9.15. *Mesogondolella* sp.

口视. *M. altudaensis* 和 *M. prexuanhanensis* sp. nov. 之间的过渡类型,代表着 *M. altudaensis* 的齿台(尤其是后部)开始收缩变窄的演化阶段。采集号:L-61,L-61,L-61;登记号:121166—121168。"孤峰组"*M. altudaensis* 带上部。

图 版 Ⅲ

1. *Mesogondolella prexuanhanensis* sp. nov.

1a. 口视;1b.同一标本之侧视;为 *M. prexuanhanensis* sp. nov. 和 *M. xuanhanensis* sp. nov. 之间的过渡类型。采集号:L-76;登记号:121169。"孤峰组"*M. prexuanhanensis* 带。

2—10.14. *Mesogondolella xuanhanensis* sp. nov.

2a,3,4b,5a,6,7,8a,9a,10a,14b. 口视;2b,5b,8b,9b,10b,14a. 分别为 2a,5a,8a,9a,10a,14b 之侧视;4a. 为 4b 之前侧斜视;2.为早期分子,9 为末期分子,10 为年轻个体;8 为 Holotype。采集号:L-87,L-100,L-94,L-96,L-98.1,L-100,L-99,L-103,L-101,L-102.5;登记号:121170—121179。"孤峰组"*M. xuanhanensis* 带。

11. *Clarkina liangshanensis*?（Wang)

口视。采集号:L-125;登记号:121180。吴家坪组底部 *C. liangshanensis*? 带。

12.13. *Clarkina leveni* (Kozur,Mostler and Pjatakova)

口视。采集号:L-151;登记号:121181,121182。吴家坪组 *C. leveni* 带。

15. *Clarkina orientalis* (Barskov and Koroleva)

口视, ×50.采集号:L-241;登记号:121183。吴家坪组 *C. orientalis* 带。