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## 河西走廊东部香山群时代和物源讨论

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**摘要:** 香山群是一套经历轻微区域变质作用的陆源碎屑岩, 夹有少量碳酸盐岩和硅质岩, 主要位于河西走廊东部香山地区。迄今为止, 前人已经做过大量工作, 但是对香山群与该区奥陶纪米钵山组的关系、香山群的时代以及香山群的物源等问题还存在较大争议。笔者对香山群的碎屑锆石做了定年(LA-ICP-MS)工作, 通过香山群与米钵山组锆石年龄的对比, 发现米钵山组最年轻锆石(451±8) Ma 比香山群最年轻锆石(525±3) Ma 年轻, 且香山群不含米钵山组其他年轻锆石成分, 香山群时代应该晚于(525±3) Ma, 而早于中奥陶世米钵山组, 应属中一晚寒武世。香山群碎屑锆石年龄谱与华夏地块、阿拉善基底、华北西部和北祁连岩浆变质事件年龄差异显著, 华夏地块、阿拉善基底、华北西部和北祁连不是香山群物源, 而与澳大利亚西南部地区相似, 同时根据香山群古水流分析结果, 推测澳大利亚西南部可能是香山群的沉积物源。

**关键词:** 香山群; 碎屑锆石; 古水流; 寒武纪; 物源

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## A discussion on the provenance and age of Xiangshan Group in Eastern Hexi Corridor

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**Abstract:** The Xiangshan Group is composed of a set of marine clastic rocks with small amounts of limestone and siliceous rocks, which experienced the greenschist facies metamorphism, and is located mainly in the eastern Hexi Corridor. The comparison between

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the detrital zircon ages (LA-ICP-MS) of the Xiangshan Group and the Miboshan Formation shows that the youngest zircon ( $451 \pm 8$ ) Ma of Miboshan Formation is younger than the youngest ( $525 \pm 3$ ) Ma of the Xiangshan Group, and Xiangshan Group does not contain other young zircons as the Miboshan Formation. Therefore, the age of Xiangshan Group should be younger than ( $525 \pm 3$ ) Ma and older than the Ordovician Miboshan Formation. The Xiangshan Group may be the Middle-Late Cambrian in age. Furthermore, the striking comparison between detrital zircon ages of the Xiangshan Group with the ages of magmatic and/or metamorphic events of southwest Australia, Cathaysia Block, the basement of Alxa Block, the western margin of North China Block, and the North Qilian Orogenic Belt shows that the possibility of Cathaysia Block, the basement of Alxa Block, the western margin of North China Block, and the North Qilian Orogenic Belt as the provenance of Xiangshan Group should be ruled out. Combined with paleocurrent data of the Xiangshan Group, the authors argue that the southwestern Australia might have been the main provenance of the Xiangshan Group.

**Key words:** Xiangshan Group; detrital zircon; paleocurrent; Cambrian; provenance

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香山群是一套区域浅变质、厚度巨大,以深水浊流沉积为主的复理石建造,夹有少量碳酸盐岩和硅质岩<sup>[1-3]</sup>。前人已经做了很多工作<sup>[3-14]</sup>,但到目前为止,香山群的时代、物源等问题还存在诸多争议<sup>[11,13,15]</sup>。这些问题的解决可为该区贺兰坳拉槽是否存在、阿拉善地块的属性及其与华北板块的关系以及河西走廊东部早古生代演化等问题提供约束。

碎屑锆石测年和古流向分析是解决香山群时代和物源的有效手段。沉积岩中广泛存在碎屑锆石,锆石富U和Th,低普通Pb,且具有非常高的矿物稳定性<sup>[16]</sup>,通过U-Pb测年可限定沉积岩成岩年龄<sup>[17]</sup>、区分沉积物源<sup>[17-19]</sup>、探讨区域构造演化<sup>[20-22]</sup>等。古流向则是分析沉积物源的最直接证据<sup>[6,23]</sup>。前人在研究区的同位素测年工作<sup>[24-31]</sup>也极大方便了我们对年龄对比,进一步分析香山群物源。

本文报道了河西走廊东部香山群碎屑锆石原位U-Pb年龄和古水流数据。在前人工作的基础上,通过香山群碎屑锆石和古水流的研究,探讨了香山群的时代和沉积物源等问题。

## 1 地质背景

研究区位于河西走廊东部,是阿拉善地块、鄂尔多斯地块和祁连造山带等几个构造单元的过渡地区(图1)。祁连造山带东侧为秦岭造山带,西侧以阿尔金断裂为界线,可以划分为北祁连造山带、中祁连地块、南祁连造山带。阿拉善地块东与鄂尔多斯地块以中生代贺兰山逆冲构造带相邻。

香山群主要分布在宁夏贺兰山南段至香山地区,从下而上可划分为徐家圈组、狼嘴子组和磨盘井组(图2)。徐家圈组主要为灰绿色轻变质中细粒长石石英砂岩、板岩及少量薄层灰岩等,厚1152.0~2785.9 m;狼嘴子组主要由灰绿色中厚层轻变质中细粒砂岩夹板岩及少量薄层灰岩等组成,顶部为黄河井段的紫红和灰色硅质岩夹板岩,总厚90.1~3178.0 m;磨盘井组岩性以灰绿色中厚层轻变质中细粒砂岩夹板岩为主,少含碳酸盐岩、硅质岩等化学沉积岩<sup>[1]</sup>。

## 2 样品采集及处理

样品SQ12-1采自宁夏中宁县喊叫水乡石泉村西北徐家圈沟内徐家圈组下部,地理坐标为:37°12'13.0" N, 105°29'28.3" E(图2)。手标本岩性是灰绿色中细粒长石石英砂岩,采集层上下可见砂岩中夹有粉砂岩和泥质粉砂岩,中薄层,层厚稳定(图3-A);镜下可见部分绢云母,说明岩石经历了部分变质作用(图3-B)。

样品SQ12-1的碎样和锆石挑选工作由河北省区域地质矿产调查研究所实验室完成,在避免污染的条件下,将样品粉碎至60目以下,接着通过水洗和电磁选方法富集锆石,最后在双目显微镜下精选锆石颗粒,选出100粒以上碎屑锆石,等待制靶。锆石样品的制靶工作和阴极发光(CL)图像的采集由北京铀年领航科技有限公司完成。将选出的碎屑锆石和标准锆石一起粘贴在环氧树脂表面制靶,将

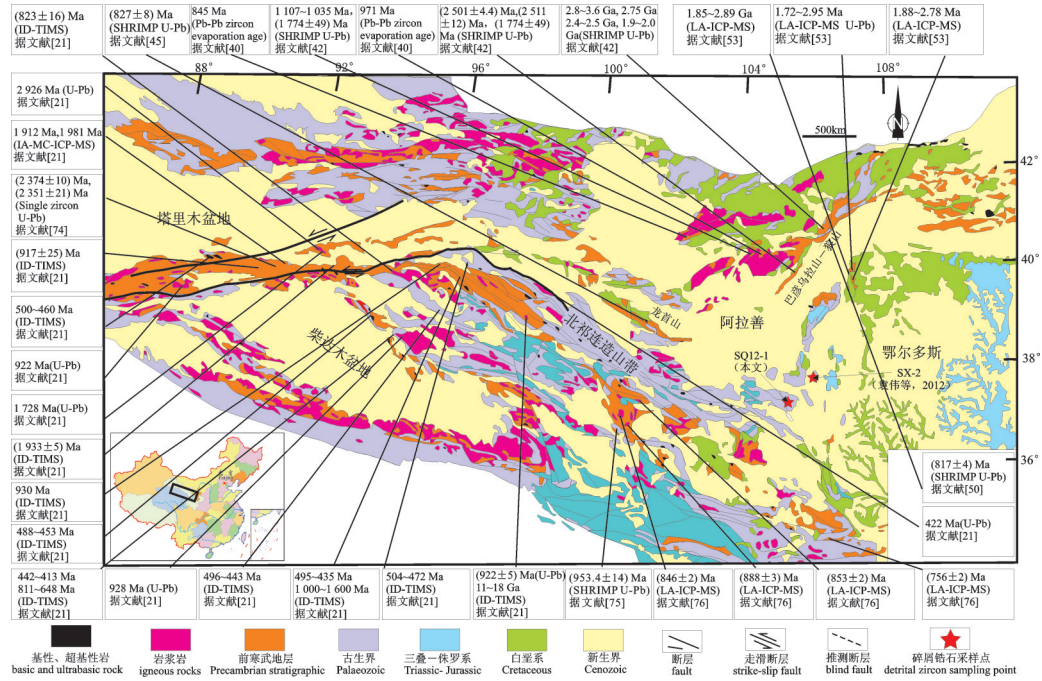


图1 河西走廊区地质图及部分年代数据分布图(据文献[24-31])  
Fig.1 Geological map of Hexi Corridor and distribution of isotopic ages (after references [24-31])

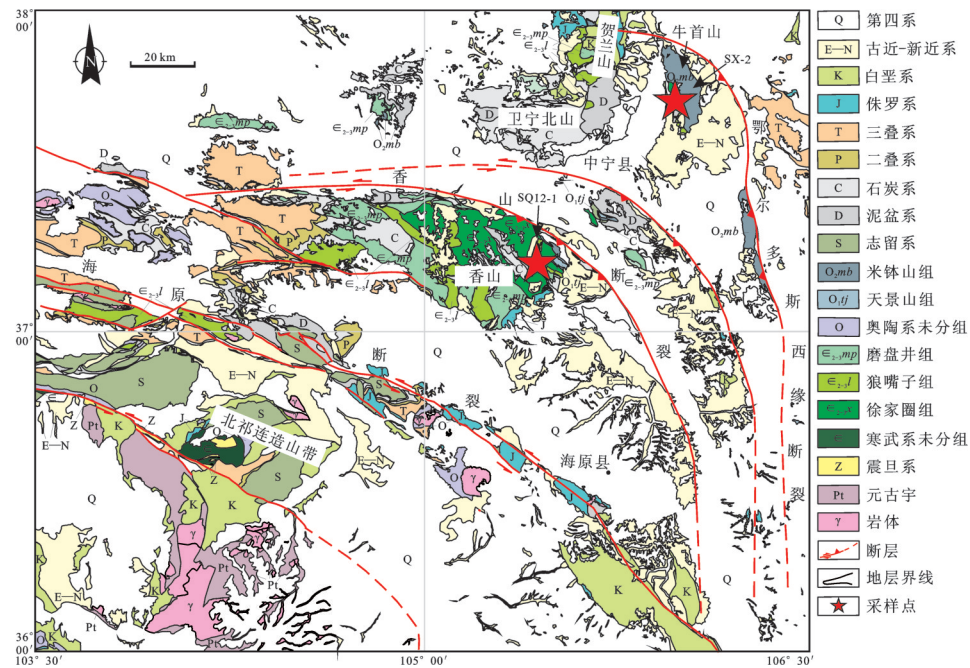


图2 研究区地质图及样品采集分布点(据①②③④修改)  
Fig.2 Geological map of the study area and sampling locations

- ① 甘肃省地质调查院. 1:25万景泰县幅区域地质调查报告. 2009.
- ② 甘肃省地质调查院. 1:25万兰州市幅区域地质调查报告. 2009.
- ③ 宁夏回族自治区地质环境监测总站. 1:25万吴忠市幅区域地质调查报告. 2010.
- ④ 宁夏回族自治区地质环境监测总站. 1:25万固原市幅区域地质调查报告. 2010.

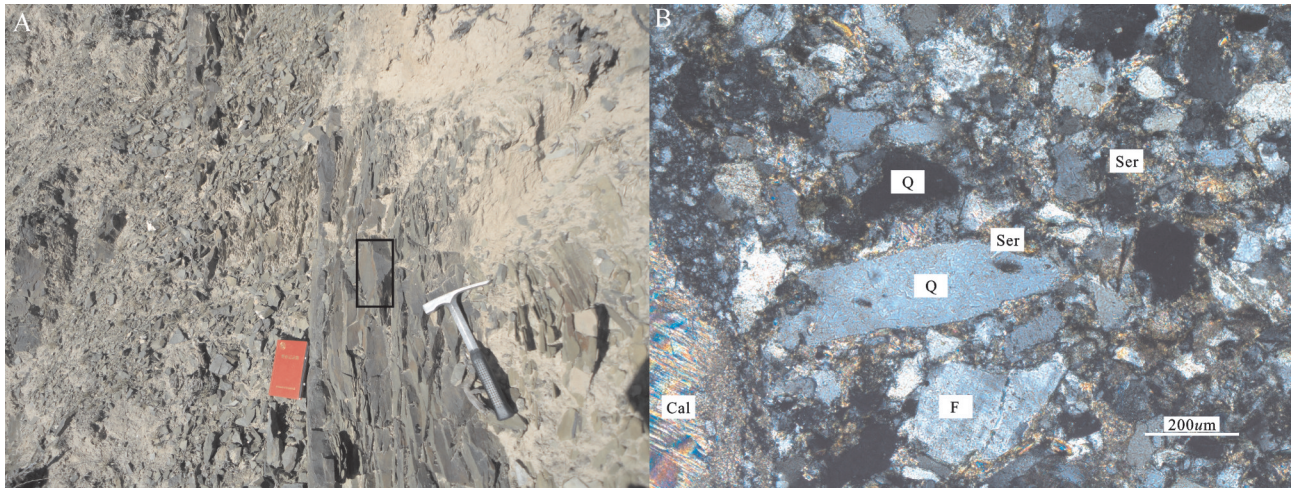


图3 香山群砂岩野外照片(A)和镜下照片(B)

Q—石英;F—长石;Cal—方解石;Ser—绢云母

Fig.3 Sandstone of Xiangshan Group (A) and microscope photograph (B)

Q— Quartz; F— Feldspar; Cal— Calcite; Ser— Sericite

待测锆石做透射光、反射光显微照相,用来观察其抛光面有无裂隙及包裹体等,然后进行阴极发光(CL)照相,用来进一步反映锆石的内部结构特征,所得部分锆石CL图像见图4。

### 3 样品测试及结果

样品(SQ12-1)LA-ICP-MS锆石U-Pb定年测试分析在中国地质调查局天津地质调查中心实验室完成。实验所用多接收器电感耦合等离子体质谱仪(Neptune)由Thermo Fisher公司制造,离子光学通路采用能量聚焦和质量聚焦的双聚焦设计,并采用动态变焦(ZOOM)使质量色散达到17%。该系统配备法拉第杯接收器9个,离子计数器接收器4个。激光器(UP193-FX准分子激光器)由美国ESI公司生产,激光波长193 nm,脉冲宽度5 ns,束斑直径2~150 μm可调,脉冲频率1~200 Hz连续可调。用He气将激光剥蚀物质送入Neptune,利用动态变焦扩大色散同时接收质量数相差很大的U-Pb同位素,从而进行锆石U-Pb同位素原位测定。外部锆石年龄标样为TEMORA,用NIST610玻璃标样作为外标计算锆石样品的Pb、U和Th含量。用ICPMSDataCal程序<sup>[32]</sup>和ISOPLOT(Version 4.1)程序<sup>[33]</sup>进行数据处理并成图,详细的实验流程见文献[34]。实验中借助锆石透射光、反射光、CL照片(图4),避开包裹体,确定测点位置,接着用193 nm

激光器对锆石进行剥蚀,激光频率为8~10 Hz,激光束斑直径为32 μm。

本次测点112个,以谐和度80%~105%遴选锆石U-Pb年龄数据,谐和度小于80%的数据不作为有效数据,不进行统计。遴选后获得有效测点数据105个,满足年龄分布统计分析的要求<sup>[19]</sup>。年龄大于1000 Ma时采用<sup>207</sup>Pb/<sup>206</sup>Pb表面年龄,小于1000 Ma时采用<sup>206</sup>Pb/<sup>238</sup>U表面年龄<sup>[35]</sup>。表1列出了所有测点数据,并绘成谐和图(图5-A),但年龄谱(图5-B)中只统计有效数据。多数锆石数据点位于和谐线附近(图5-A),少部分位于和谐线之下,说明可能存在一定的放射性铅丢失。

阴极发光图像(图4)显示锆石经历搬运作用明显,形态不完整,部分锆石仅为残片,粒径40~130 μm不等,以80 μm居多,长宽比约为2:1;大多数为不规则粒状或浑圆状,磨圆度较好,说明经过了较远距离的搬运;部分锆石(图4中锆石48和34)磨圆度较差,搬运距离较短。锆石U含量为 $37 \times 10^{-6}$ ~ $1104 \times 10^{-6}$ ,Th/U比值为0.04~2.6,其中101颗锆石(占96.2%)的Th/U > 0.13,4颗锆石的Th/U为0.04~0.13。结合测试所得数据和锆石内部结构,Th/U大于0.13的锆石多数呈自形或半自形结构,具有振荡环带(图4中锆石12、16、50、32、18、1、72、44、52、43和86等)、均质或不规则分带结构(图4中锆石75和95等),也有部分锆石U含量较低(图4中锆石54、

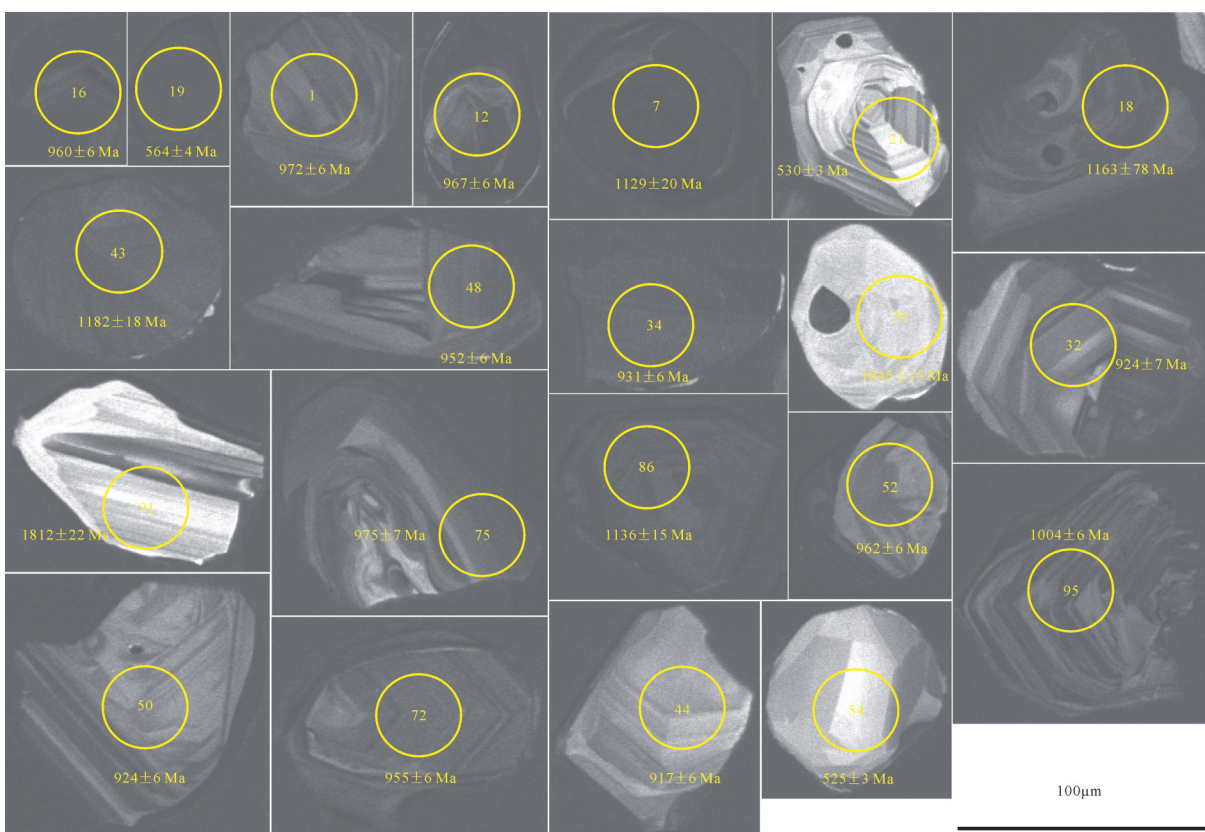


图4 样品SQ12-1部分碎屑锆石CL图像及年龄(圆圈内为点号)

Fig.4 CL images of typical detrital zircons and U-Pb ages of sample SQ12-1 (The unit of geological age is Ma, and the number of zircons is in the circles)

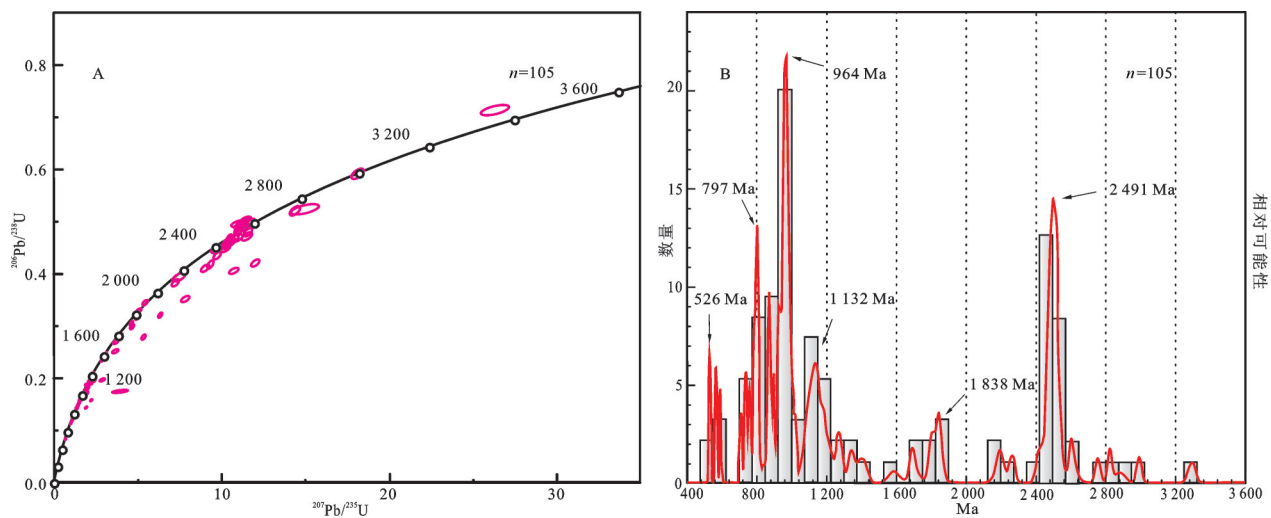


图5 样品SQ12-1  $^{207}\text{Pb}/^{235}\text{U}-^{206}\text{Pb}/^{238}\text{U}$  谐和图(A)和锆石年龄频谱(B)

Fig. 5  $^{207}\text{Pb}/^{235}\text{U}-^{206}\text{Pb}/^{238}\text{U}$  concordia diagram (A) and age histogram of sample SQ12-1 (B)

21、91和70等),CL图像较亮,可能来自偏碱性的花岗岩中,结合锆石形态和Th、U等元素含量及比值特征,这些锆石可识别为岩浆锆石;另外,部分锆石可能受变质作用发生重结晶(图4中锆石19、48和7等),Th/U比值也较小,可能为变质成因锆石。

样品SQ12-1锆石年龄主要可分为5个谱段(图5-B),705~804 Ma间共有13颗锆石,占总数的12.4%,峰值为794 Ma;859~1 021 Ma之间共有锆石30颗,占总数的28.6%,峰值为964 Ma;1 070~1 217 Ma间共有锆石13颗,占全部锆石的12.4%,峰值为1 132 Ma;在1 584~1 854 Ma间共有锆石8颗,占全部锆石的7.6%,峰值为1 838 Ma;另外,在2 439~2 533 Ma间还分布有一些锆石年龄,峰值是2 491 Ma。本次获得最年轻锆石年龄为(525±3) Ma和最老锆石年龄为(3 291±20) Ma(表1)。最年轻的锆石(图4中锆石54)年龄(525±3) Ma,呈粒状,磨圆度好,宽约75 μm, Th/U=0.78。

## 4 问题讨论

### 4.1 香山群时代分析

香山群的时代问题虽然历经近60年的研究,但目前还存在明显分歧。边兆祥<sup>[6]</sup>将其称为南山系并入奥陶—志留纪。1960年宁夏区测队建立香山群,细分为米钵山麓组、上石棚组、香山寺组、吕家新庄组,时代属晚奥陶世至早志留世<sup>[1]</sup>。宁夏区测队(1965)将米钵山麓组下部的碎屑岩剔出,新建米钵山组,时代为晚奥陶世;将米钵山麓组上部的灰岩夹板岩、上石棚组、香山寺组、吕家新庄组命为香山群第一、二、三、四亚群,时代定为中寒武世,米钵山组和新建香山群呈断层接触<sup>[1]</sup>。20世纪90年代区域地质填图及地层清理工作又将香山群第一亚群划归米钵山组上部,时代属于奥陶纪;将香山群第二、三、四亚群分别命为徐家圈组、狼嘴子组、磨盘井组,时代属晚寒武世,香山群与米钵山组呈断层接触<sup>[37]</sup>。

目前对香山群时代的观点主要有:(1)香山群较米钵山组新,两者之间呈整合接触关系,同属奥陶纪<sup>[1]</sup>;(2)香山群时代比米钵山组老,两者呈断层接触,香山群属晚寒武世,米钵山组属奥陶纪<sup>[2,5,9,10,13,37]</sup>;(3)香山群时代为中—晚寒武世<sup>[1]</sup>;(4)将香山群解体,第一、第三亚群为中—晚寒武世,第二和第四亚

群为奥陶纪<sup>[38]</sup>。

本文通过香山群碎屑锆石的研究来探讨香山群与米钵山组之间的关系以及香山群的时代,锆石的最小年龄可代表地层沉积的下限<sup>[17,39]</sup>。结合前人<sup>[40]</sup>研究结果,笔者将香山群与米钵山组<sup>[13]</sup>作了对比(图6),通过碎屑锆石分析香山群与米钵山组的时代关系,进而限定香山群时代。

本文样品SQ12-1采自香山群底部,最年轻锆石年龄为(525±3) Ma(图6-C),且有年轻成分(529±3) Ma、(562±4) Ma、(563±4) Ma等(表1)。袁伟(2012)<sup>[40]</sup>获得香山群样品SX-2中最年轻锆石年龄为(642±15) Ma(图6-D)。本文报道的最小年龄(525±3) Ma(SQ12-1)较袁伟等(2012)报道的最小年龄年轻,因此,香山群沉积时代应该晚于525 Ma。

将香山群(SQ12-1和SX-2)锆石年龄与贺兰山西侧不同地区的米钵山组锆石年龄(张进等,2012)<sup>[13]</sup>作比较(图6),笔者发现米钵山组最小锆石年龄(451±8) Ma(Alxa-1)、(483±4) Ma(Alxa-1)比香山群最小锆石年龄(525±3) Ma(SQ12-1)、(642±15) Ma(SX-2)要年轻得多。另外,香山群碎屑锆石(SQ12-1和SX-2)中不含米钵山组(Alxa-1和Alxa-2)其他年轻成分(517 Ma、505 Ma和447 Ma等)。一般而言,沉积时代越晚,岩石中所含最年轻碎屑锆石年龄应该更小,因此笔者推测香山群的沉积时代应该早于米钵山组。米钵山组为中奥陶世,有大量的化石为依据<sup>[2,3,5,9,10,11,37]</sup>,香山群时代应该早于奥陶纪且晚于(525±3) Ma,应属中—晚寒武世。

### 4.2 香山群的物源

#### 4.2.1 碎屑锆石

香山群(SQ12-1和SX-2)锆石年龄谱显示:在500~600 Ma之间有一个峰值561 Ma;在700~800 Ma之间有一个峰值为797 Ma;在900~1100 Ma内出现主峰值,为955 Ma;在1 100~1 200 Ma之间也存在一个1 156 Ma的峰值;与其他年龄段相比,虽然1 500~1 800 Ma间锆石数量不多,但也可作为一个段分析,峰值为1 725 Ma;另外在2 400~2 700 Ma之间有一个次级段,峰值为2 451 Ma(图7-A)。

研究区位于华北板块的西缘,将香山群碎屑锆石年龄(图7-A)与华北西缘岩浆变质事件年龄做对比。从图7-E中可以看到华北西部主要岩浆和变质发生在1 800~2 100 Ma(峰值1 926 Ma)和

2 400~2 800 Ma(峰值2 512 Ma和2 696 Ma)两个区间。华北西缘岩浆和变质事件年龄分布与香山群的年龄谱相差较大,推测其为香山群提供物源的可能性不大。

北祁连造山带位于研究区的西南部(图1)。北祁连造山带年龄谱(图7-F)最主要的峰值为446 Ma左右,该峰值小于(525±3) Ma,不作对比。北祁连存在晋宁期事件记录,峰值为850 Ma左右,如牛心山片麻状花岗岩的结晶年龄为(776±10) Ma<sup>[41]</sup>,北祁连西段片麻状二长花岗岩结晶年龄(985±10) Ma<sup>[42]</sup>;另外也存在一个955 Ma的峰值。就整个年龄谱段对比而言,香山群和北祁连造山带相差甚远,北祁连造山带不太可能是香山群的物源区。

研究前人关于阿拉善基底岩浆变质事件年龄(图7-D)后发现,主峰值在800~1 000 Ma之间,为894 Ma;在1 700~2 000 Ma之间存在构造热事件形成的锆石,峰值为1 800 Ma和1 964 Ma,如阿拉善庆格勒黑云斜长片麻岩的单颗粒锆石年龄(1 826±13) Ma<sup>[43]</sup>,叠布斯格群片麻状花岗岩变质年龄(1 856±12) Ma和(1 923±28) Ma<sup>[44]</sup>。另外,也见一个2 329 Ma的峰值。阿拉善基底岩浆变质事件年龄与香山群锆石年龄有可对应的峰值,但是也有很大不同。

澳大利亚西南部与华夏地块的岩浆变质事件年龄与香山群碎屑锆石年龄分布较为相近(图7),在此进行详细对比。两者都存在500~600 Ma锆石,其中澳大利亚西南部峰值为522 Ma,而华夏地块峰值为533 Ma;在900~1 000 Ma区间内,澳大利亚西南部峰值为976 Ma,华夏地块峰值为997 Ma;在1 100~1 300 Ma之间华夏地块峰值为1 118 Ma而澳大利亚峰值为1 204 Ma,900~1 300 Ma之间的锆石可能代表着格林威尔造山事件<sup>[68-70]</sup>;1 500~1 900 Ma间澳大利亚西南部峰值为1 646 Ma,虽然华夏地块有相当锆石分布,但没有显示峰值;另外在2 400~2 700 Ma之间华夏地块峰值为2 459 Ma,澳大利亚西南部峰值为2 600 Ma(图7-B)。将澳大利亚西南部和华夏地块岩浆变质事件年龄与香山群碎屑锆石年龄对比,笔者发现无论从年龄谱段划分还是各谱段年龄峰值,香山群与澳大利亚西南部的匹配程度要比华夏地块更高。

在新元古代末,阿拉善地体、华夏地块可能与澳大利亚西南部是连接在一起的<sup>[71]</sup>。华夏地块、澳

大利亚板块和阿拉善地体的Hf同位素特征也显示了相似的早期地壳演化历史<sup>[40,72]</sup>,体现了华夏地块、阿拉善地块和澳大利亚的岩浆变质事件年龄有一定程度的相似性。但是仔细区分,华夏地块没有与香山群1 725 Ma峰值对应的峰值;阿拉善地块锆石年龄分布主峰值为894 Ma和1 964 Ma(晋宁期),无香山群中较为重要的1 156 Ma峰值附近的峰值。而澳大利亚西南部晋宁期976 Ma的主峰值与香山群964 Ma的主峰值对应,澳大利亚西南部次峰值1 152 Ma和1 646 Ma分别与香山群次峰值1 156 Ma和1 725 Ma对应,另外,在500~600 Ma之间,澳大利亚西南部加里东事件年龄峰值为522 Ma,与香山群561 Ma峰值较为接近,所以,就碎屑锆石数据而言,澳大利亚西南部可能是香山群的最终物源,当然也不排除香山群是再旋回沉积产物的可能性。

#### 4.2.2 古流向

在进行物源分析时,最直接的证据就是古流向。古流向的信息会在沉积地层中以特定的形式保留下来,通过指向沉积构造的研究可获得古水流方向<sup>[6,23]</sup>。本次古水流数据分别采自米钵山南麓徐家圈组(A和B)、上石棚(C和D)、王家满(E和F)、大树沟(G)和石峁子(H和I)等地,校正结果见图8。

在A采集点处,斜层理位于米钵山南麓徐家圈组紫红色中细粒砂岩中,地层产状 $235^{\circ}\angle 86^{\circ}$ ,校正后得到古流向玫瑰花图如图8,指示古水流流向SWW方向,即碎屑物质的源区位于其NEE方位。B点斜层理测于米钵山南麓徐家圈组黄绿色、灰绿色泥质粉砂岩中,野外露头明显,地层产状 $235^{\circ}\angle 64^{\circ}$ ,经过校正后显示古水流流向近SWW方向(图8),指示物源在其NEE方向。C和D点数据采自上石棚徐家圈组,出露不全,推测为斜层理,其中C点岩性为薄层粉砂岩、泥质粉砂岩与薄层中细粒砂岩,古水流采集于薄层砂岩内,层厚3~5 m,地层产状 $105^{\circ}\angle 62^{\circ}$ ,校正后显示古水流来自SW方向(图8);D点处岩性为厚层砂岩夹薄层灰绿色泥质粉砂岩,古水流位于灰绿色泥质粉砂岩中,厚约1 m,地层产状 $224^{\circ}\angle 88^{\circ}$ ,校正后古水流流向近S方位(图8)。E和F点古水流来自王家满徐家圈组,为斜层理,E点古水流采自于土黄色粉砂岩,上下岩性不明,但从延伸出远处岩石可看出上下均为灰绿色板岩或轻变质砂岩,砂岩中片理化强烈,地层产状 $65^{\circ}\angle 26^{\circ}$ ,F点

表 1 样品 SQ12-1 的 LA-ICP-MS 测试数据  
Table 1 U-Pb geochronologic analyses on SQ12-1 by LA-ICP-MS

测点号	含量/ $10^{-6}$		同位素比值										年龄/Ma		谐和度 %				
	Pb	U	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$	$^{208}\text{Pb}/^{232}\text{Th}$	$1\sigma$	$^{232}\text{Th}/^{238}\text{U}$	$1\sigma$	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$		$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$
SQ121.1	67	352	0.1628	0.0011	1.606	0.0147	0.0715	0.0006	0.0551	0.0038	0.8039	0.0020	0.972	6	972	9	973	16	100
SQ121.2	50	92	0.4906	0.0033	11.30	0.1052	0.1671	0.0013	0.1382	0.0015	0.3735	0.0011	2573	17	2548	24	2529	13	102
SQ121.3	116	659	0.1616	0.0011	1.701	0.0150	0.0763	0.0006	0.0601	0.0012	0.4729	0.0017	966	6	1009	9	1104	15	87
SQ121.4	84	504	0.1662	0.0011	1.648	0.0164	0.0719	0.0006	0.0520	0.0032	0.2732	0.0011	991	7	989	10	983	17	101
SQ121.5	20	37	0.4819	0.0033	10.98	0.0967	0.1652	0.0013	0.1363	0.0013	0.5078	0.0070	2535	17	2521	22	2510	13	101
SQ121.6	98	631	0.1441	0.0009	1.908	0.0164	0.0960	0.0007	0.0518	0.0020	0.4042	0.0071	868	6	1084	9	1548	14	56
SQ121.7	221	936	0.2455	0.0016	3.024	0.0370	0.0893	0.0010	0.0772	0.0020	0.0696	0.0005	1415	9	1414	17	1411	21	100
SQ121.8	31	141	0.1909	0.0012	2.035	0.0225	0.0773	0.0008	0.0675	0.0013	0.6782	0.0029	1126	7	1127	12	1129	20	100
SQ121.9	56	270	0.1667	0.0011	1.665	0.0157	0.0725	0.0006	0.0702	0.0011	0.8635	0.0018	994	7	995	9	999	16	99
SQ121.10	60	465	0.1325	0.0009	1.203	0.0112	0.0659	0.0005	0.0436	0.0030	0.2029	0.0008	802	6	802	7	802	17	100
SQ121.11	51	85	0.4803	0.0031	11.57	0.1049	0.1747	0.0012	0.1278	0.0025	0.9546	0.0029	2529	17	2570	23	2603	12	97
SQ121.12	216	467	0.4114	0.0030	8.989	0.0999	0.1585	0.0016	0.1160	0.0010	0.4861	0.0009	2221	16	2337	26	2439	17	91
SQ121.13	40	210	0.1618	0.0011	1.592	0.0178	0.0713	0.0007	0.0494	0.0008	0.9500	0.0070	967	6	967	11	967	21	100
SQ121.14	46	319	0.1295	0.0009	1.172	0.0100	0.0657	0.0005	0.0394	0.0020	0.7288	0.0024	785	5	788	7	796	15	99
SQ121.15	83	465	0.4216	0.0028	11.98	0.1040	0.2060	0.0016	0.0925	0.0026	0.7357	0.0022	2268	15	2602	23	2875	13	79
SQ121.16	431	894	0.4060	0.0027	10.73	0.1098	0.1916	0.0017	0.1088	0.0013	0.6662	0.0019	2197	15	2500	26	2756	15	80
SQ121.17	123	313	0.3215	0.0021	6.321	0.0599	0.1426	0.0012	0.1320	0.0011	0.6523	0.0016	1797	12	2021	19	2259	15	80
SQ121.18	77	467	0.1607	0.0010	1.571	0.0131	0.0709	0.0005	0.0518	0.0025	0.3416	0.0015	960	6	959	8	955	15	101
SQ121.19	164	343	0.4676	0.0031	10.73	0.1012	0.1664	0.0013	0.1307	0.0010	0.0628	0.0000	2473	16	2500	24	2522	13	98
SQ121.20	61	296	0.1889	0.0012	2.048	0.0824	0.0786	0.0031	0.0525	0.0005	0.6447	0.0016	1115	7	1132	46	1163	78	96
SQ121.21	9	78	0.0914	0.0006	0.7444	0.0071	0.0591	0.0005	0.0283	0.0006	1.442	0.0010	564	4	565	5	570	18	99



续表1

测点号	含量/ $10^{-6}$		同位素比值										年龄/Ma		谱和度				
	Pb	U	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$	$^{208}\text{Pb}/^{232}\text{Th}$	$1\sigma$	$^{232}\text{Th}/^{238}\text{U}$	$1\sigma$	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$	%
SQ121.22	50	369	0.1234	0.0008	1.097	0.0131	0.0645	0.0007	0.0349	0.0005	0.6811	0.0010	750	5	752	9	757	23	99
SQ121.23	29	319	0.0856	0.0006	0.6916	0.0067	0.0586	0.0005	0.0257	0.0019	0.6058	0.0018	530	3	534	5	551	18	96
SQ121.24	97	324	0.2793	0.0018	5.341	0.0556	0.1387	0.0013	0.0842	0.0012	0.3102	0.0002	1588	10	1875	20	2211	46	72
SQ121.25	60	95	0.5214	0.0035	14.36	0.1219	0.1998	0.0015	0.1380	0.0013	0.7440	0.0016	2705	18	2774	24	2824	12	96
SQ121.26	139	548	0.2367	0.0016	2.850	0.0401	0.0873	0.0012	0.0667	0.0008	0.5370	0.0011	1369	9	1369	19	1368	26	100
SQ121.27	24	170	0.1284	0.0009	1.154	0.0102	0.0651	0.0005	0.0433	0.0020	0.6189	0.0002	779	5	779	7	779	15	100
SQ121.28	267	546	0.4586	0.0033	10.34	0.0873	0.1635	0.0012	0.1135	0.0022	0.2679	0.0011	2434	18	2465	21	2492	12	98
SQ121.29	67	123	0.4609	0.0031	10.55	0.0923	0.1660	0.0013	0.1260	0.0010	0.6876	0.0039	2444	17	2485	22	2518	13	97
SQ121.30	96	448	0.1868	0.0013	2.008	0.0173	0.0779	0.0006	0.0557	0.0026	0.8236	0.0010	1104	8	1118	10	1145	15	96
SQ121.31	117	280	0.3835	0.0026	7.241	0.0910	0.1369	0.0016	0.1247	0.0008	0.3622	0.0013	2093	14	2142	27	2189	20	96
SQ121.32	24	204	0.1156	0.0008	1.003	0.0103	0.0629	0.0006	0.0348	0.0011	0.4160	0.0006	705	5	705	7	705	20	100
SQ121.33	32	246	0.1197	0.0008	1.056	0.0090	0.0640	0.0005	0.0900	0.0029	0.2485	0.0006	729	5	732	6	740	16	98
SQ121.34	181	285	0.5257	0.0038	14.94	0.3489	0.2069	0.0044	0.1425	0.0034	0.7155	0.0016	2715	20	2811	66	2881	35	94
SQ121.35	35	199	0.1541	0.0011	1.490	0.0125	0.0701	0.0005	0.1080	0.0009	0.3645	0.0007	924	7	926	8	932	16	99
SQ121.36	146	689	0.1975	0.0013	2.250	0.0207	0.0826	0.0006	0.0549	0.0007	0.5662	0.0006	1162	8	1197	11	1260	15	92
SQ121.37	121	786	0.1553	0.0010	1.505	0.0141	0.0703	0.0006	0.0430	0.0011	0.2539	0.0002	931	6	932	9	937	18	99
SQ121.38	141	897	0.1574	0.0010	1.538	0.0316	0.0709	0.0012	0.0519	0.0017	0.2435	0.0016	942	6	946	19	954	34	99
SQ121.39	65	398	0.1571	0.0011	1.524	0.0130	0.0704	0.0005	0.0518	0.0029	0.4095	0.0008	940	7	940	8	939	15	100
SQ121.40	240	819	0.2994	0.0020	4.624	0.0474	0.1120	0.0010	0.0993	0.0011	0.0525	0.0003	1688	11	1754	18	1832	17	92
SQ121.41	25	199	0.1207	0.0008	1.067	0.0103	0.0641	0.0006	0.0321	0.0012	0.5987	0.0014	735	5	737	7	745	18	99
SQ121.42	78	396	0.1950	0.0013	2.311	0.0485	0.0859	0.0007	0.0604	0.0018	0.2573	0.0005	1148	7	1216	26	1337	16	86
SQ121.43	174	432	0.3941	0.0035	7.4448	0.1441	0.1370	0.0026	0.1026	0.0007	0.1746	0.0004	2142	19	2166	42	2190	33	98
SQ121.44	13	92	0.1296	0.0009	1.164	0.0090	0.0652	0.0005	0.0406	0.0008	0.5906	0.0193	785	5	784	6	779	15	101
SQ121.45	169	1104	0.1590	0.0011	1.561	0.0134	0.0712	0.0007	0.0462	0.0032	0.1374	0.0002	951	6	955	8	964	20	99

续表1

测点号	含量/ $10^{-6}$		同位素比值						年龄/Ma				谱和度 %	
	Pb	U	$^{206}\text{Pb}/^{238}\text{U}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{208}\text{Pb}/^{232}\text{Th}$	$^{232}\text{Th}/^{238}\text{U}$	$^{206}\text{Pb}/^{238}\text{U}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{207}\text{Pb}/^{206}\text{Pb}$	1 $\sigma$	1 $\sigma$		1 $\sigma$
SQ121.46	310	789	0.3515	0.0025	0.1612	0.1692	0.2636	1.042	14	2210	26	2468	17	79
SQ121.47	59	322	0.1687	0.0011	0.0794	0.0476	0.6331	1005	7	1062	11	1182	18	85
SQ121.48	52	313	0.1529	0.0010	0.0695	0.0412	0.6343	917	6	916	10	912	19	101
SQ121.49	84	295	0.2808	0.0019	0.1036	0.0899	0.2269	1595	11	1637	16	1690	15	94
SQ121.50	54	382	0.1327	0.0009	0.0662	0.0407	0.5439	804	5	806	9	814	15	99
SQ121.51	97	313	0.2709	0.0018	0.0979	0.0737	0.8361	1546	10	1562	27	1584	31	98
SQ121.52	23	112	0.1591	0.0011	0.0706	0.0433	1.606	952	6	950	24	945	40	101
SQ121.53	95	458	0.1971	0.0014	0.1061	0.1266	0.1654	1169	8	1377	29	1733	38	67
SQ121.54	12	66	0.1722	0.0012	0.0769	0.0507	0.4329	1024	7	1055	10	1118	15	92
SQ121.55	117	735	0.1540	0.0010	0.0696	0.0419	0.4355	924	6	922	10	917	22	101
SQ121.56	48	295	0.1490	0.0010	0.0687	0.0489	0.6262	895	6	894	9	889	19	101
SQ121.57	41	223	0.1609	0.0011	0.0716	0.0526	0.7136	962	6	965	19	973	34	99
SQ121.58	107	477	0.1757	0.0012	0.1613	0.1591	0.3459	1044	7	1615	79	2470	12	42
SQ121.59	105	202	0.4498	0.0029	0.1648	0.1392	0.5580	2394	16	2455	26	2505	12	96
SQ121.60	33	341	0.0849	0.0005	0.0580	0.0281	0.7779	525	3	526	12	529	16	99
SQ121.61	114	216	0.4679	0.0031	0.1675	0.1366	0.4697	2474	17	2506	41	2533	25	98
SQ121.62	18	118	0.1480	0.0010	0.0691	0.0535	0.4110	890	6	893	20	902	30	99
SQ121.63	48	173	0.2517	0.0017	0.1046	0.0945	0.4483	1447	10	1556	31	1707	34	85
SQ121.64	22	97	0.1612	0.0011	0.0710	0.0547	0.0013	1.514	6	962	10	959	19	100
SQ121.65	26	265	0.0911	0.0006	0.0589	0.0285	0.5622	562	4	562	9	562	33	100
SQ121.66	15	104	0.1251	0.0008	0.0646	0.0371	0.7652	760	5	760	6	761	15	100
SQ121.67	83	119	0.4952	0.0032	0.1629	0.1306	1.772	2593	17	2533	23	2486	12	104
SQ121.68	96	185	0.4723	0.0033	0.1765	0.1564	0.2610	2494	17	2564	26	2621	23	95
SQ121.69	21	119	0.1328	0.0009	0.0662	0.0390	1.481	804	5	806	18	812	25	99

续表1

测点号	含量/ $10^{-6}$		同位素比值										年龄/Ma				谱和度		
	Pb	U	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$	$^{208}\text{Pb}/^{232}\text{Th}$	$1\sigma$	$^{232}\text{Th}/^{238}\text{U}$	$1\sigma$	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$	%
SQ121.70	10	49	0.2089	0.0014	2.284	0.0215	0.0793	0.0006	0.0652	0.0021	0.2331	0.0006	1223	8	1207	11	1180	15	104
SQ121.71	101	209	0.4184	0.0032	9.310	0.0822	0.1614	0.0012	0.1123	0.0024	0.6138	0.0051	2253	17	2369	21	2470	13	91
SQ121.72	148	304	0.4484	0.0030	9.610	0.1049	0.1554	0.0015	0.1161	0.0012	0.3739	0.0025	2388	16	2398	26	2407	17	99
SQ121.73	16	69	0.1832	0.0012	1.918	0.0177	0.0759	0.0006	0.0496	0.0008	1.584	0.0038	1084	7	1087	10	1093	16	99
SQ121.74	50	298	0.1632	0.0011	1.617	0.0127	0.0718	0.0006	0.0443	0.0008	0.4485	0.0003	975	7	977	8	981	16	99
SQ121.75	58	337	0.1639	0.0011	1.628	0.0165	0.0721	0.0007	0.0440	0.0015	0.5224	0.0004	978	7	981	10	987	19	99
SQ121.76	23	66	0.3183	0.0021	4.949	0.0454	0.1128	0.0009	0.0838	0.0014	0.6261	0.0024	1781	12	1811	17	1845	15	97
SQ121.77	110	637	0.1731	0.0011	1.987	0.0172	0.0833	0.0007	0.0670	0.0011	0.1705	0.0001	1029	7	1111	10	1275	15	81
SQ121.78	86	560	0.1596	0.0011	1.574	0.0152	0.0715	0.0006	0.0487	0.0008	0.1278	0.0008	955	6	960	9	972	18	98
SQ121.79	39	282	0.1315	0.0009	1.193	0.0132	0.0658	0.0008	0.0371	0.0009	0.5034	0.0003	796	5	797	9	800	24	99
SQ121.80	31	213	0.1320	0.0009	1.203	0.0120	0.0661	0.0006	0.0371	0.0013	0.6605	0.0005	799	5	802	8	810	19	99
SQ121.81	30	154	0.1634	0.0011	1.607	0.0175	0.0714	0.0008	0.0456	0.0010	1.026	0.0022	975	7	973	11	967	22	101
SQ121.82	27	164	0.1588	0.0010	1.554	0.0141	0.0710	0.0006	0.0445	0.0009	0.3661	0.0007	950	6	952	9	957	17	99
SQ121.83	56	293	0.1701	0.0011	1.760	0.0148	0.0751	0.0008	0.0457	0.0025	0.8438	0.0021	1013	7	1031	9	1070	21	95
SQ121.84	94	197	0.4621	0.0058	10.38	0.0931	0.1629	0.0045	0.1215	0.0005	0.1349	0.0010	2449	31	2469	22	2486	47	98
SQ121.85	16	130	0.0953	0.0006	0.7846	0.0069	0.0597	0.0005	0.0257	0.0018	1.598	0.0032	587	4	588	5	594	17	99
SQ121.86	67	203	0.3061	0.0020	4.631	0.0396	0.1097	0.0008	0.0828	0.0026	0.5175	0.0016	1722	12	1755	15	1795	13	96
SQ121.87	98	201	0.4348	0.0029	9.725	0.0857	0.1622	0.0012	0.1104	0.0029	0.5184	0.0016	2328	16	2409	21	2479	13	94
SQ121.88	118	217	0.4645	0.0032	10.43	0.1148	0.1629	0.0016	0.1105	0.0018	0.7859	0.0023	2459	17	2474	27	2486	17	99
SQ121.89	41	198	0.1840	0.0013	2.050	0.0198	0.0808	0.0007	0.0493	0.0009	0.8184	0.0020	1089	7	1132	11	1217	18	89
SQ121.90	44	298	0.1443	0.0010	1.356	0.0254	0.0682	0.0014	0.0388	0.0011	0.4247	0.0016	869	6	870	16	874	43	99
SQ121.91	14	73	0.1601	0.0011	1.576	0.0141	0.0714	0.0006	0.0484	0.0015	0.9869	0.0046	958	7	961	9	969	16	99
SQ121.92	71	404	0.1853	0.0012	1.982	0.0215	0.0776	0.0006	0.0591	0.0029	0.0389	0.0002	1096	7	1109	12	1136	15	96
SQ121.93	231	335	0.5916	0.0040	18.10	0.1609	0.2218	0.0020	0.1441	0.0024	0.5102	0.0040	2996	21	2995	27	2994	14	100

续表1

测点号	含量/ $10^{-6}$		同位素比值										年龄/Ma		谐和度				
	Pb	U	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$	$^{208}\text{Pb}/^{232}\text{Th}$	$1\sigma$	$^{232}\text{Th}/^{238}\text{U}$	$1\sigma$	$^{206}\text{Pb}/^{238}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$1\sigma$	$^{207}\text{Pb}/^{206}\text{Pb}$	$1\sigma$	%
SQ121.94	100	197	0.4564	0.0038	10.27	0.1030	0.1631	0.0014	0.1154	0.0012	0.4685	0.0011	2424	20	2459	25	2489	14	97
SQ121.95	63	352	0.1447	0.0010	1.368	0.0214	0.0685	0.0010	0.0535	0.0014	0.9624	0.0010	871	6	875	14	885	31	98
SQ121.96	23	103	0.1944	0.0013	2.101	0.0223	0.0784	0.0007	0.0570	0.0015	0.8161	0.0038	1145	8	1149	12	1157	19	99
SQ121.97	64	410	0.1590	0.0009	2.207	0.0228	0.1006	0.0012	0.0678	0.0023	0.7001	0.0017	951	5	1183	15	1466	23	58
SQ121.98	64	162	0.3304	0.0018	5.045	0.0612	0.1107	0.0013	0.1086	0.0029	0.8002	0.0034	1840	10	1827	22	1812	22	102
SQ121.99	209	367	0.4926	0.0029	11.09	0.1352	0.1633	0.0019	0.1501	0.0038	0.5517	0.0023	2582	15	2531	31	2490	20	104
SQ121.100	96	114	0.7133	0.0039	26.30	0.3400	0.2674	0.0034	0.2068	0.0009	0.2884	0.0004	3471	19	3358	43	3291	20	105
SQ121.101	45	228	0.1447	0.0009	1.367	0.0167	0.0685	0.0008	0.0486	0.0010	1.548	0.0036	871	5	875	11	884	24	99
SQ121.102	116	670	0.1686	0.0010	1.670	0.0202	0.0718	0.0008	0.0578	0.0029	0.3317	0.0010	1004	6	997	12	981	24	102
SQ121.103	127	214	0.4976	0.0029	11.06	0.1957	0.1612	0.0029	0.1521	0.0011	0.7047	0.0018	2603	15	2528	45	2468	30	105
SQ121.104	20	133	0.1425	0.0008	1.329	0.0176	0.0676	0.0009	0.0510	0.0012	0.4645	0.0019	859	5	858	11	858	27	100
SQ121.105	257	448	0.5021	0.0029	11.42	0.1415	0.1650	0.0020	0.1619	0.0036	0.4773	0.0009	2623	15	2558	32	2507	20	105
SQ121.106	35	66	0.4969	0.0028	11.21	0.1350	0.1636	0.0020	0.1717	0.0032	0.1688	0.0008	2600	15	2541	31	2493	20	104
SQ121.107	70	92	0.4988	0.0030	11.47	0.2001	0.1669	0.0027	0.1734	0.0012	1.704	0.0095	2608	15	2563	45	2526	27	103
SQ121.108	40	188	0.1779	0.0010	1.874	0.0224	0.0764	0.0009	0.0660	0.0026	0.7980	0.0025	1055	6	1072	13	1106	23	95
SQ121.109	151	407	0.3456	0.0019	5.400	0.0646	0.1133	0.0013	0.1318	0.0038	0.3211	0.0018	1914	11	1885	23	1854	21	103
SQ121.110	150	168	0.4832	0.0026	10.87	0.0623	0.1631	0.0020	0.1752	0.0019	2.6308	0.0113	2541	14	2512	14	2488	21	102
SQ121.111	77	347	0.1960	0.0011	2.059	0.0260	0.0762	0.0009	0.0794	0.0018	0.5689	0.0020	1154	6	1135	14	1101	25	105
SQ121.112	108	582	0.1716	0.0009	1.689	0.0229	0.0714	0.0009	0.0693	0.0015	0.4370	0.0013	1021	6	1005	14	969	27	105

注:带删除线数据为不谐和年龄,未用。谐和度计算公式= $100 * (1 - \text{abs}((^{206}\text{Pb}/^{238}\text{U})\text{Age} - (^{207}\text{Pb}/^{235}\text{U})\text{Age} - ((^{206}\text{Pb}/^{238}\text{U})\text{Age} + (^{207}\text{Pb}/^{235}\text{U})\text{Age})/2))$ 。

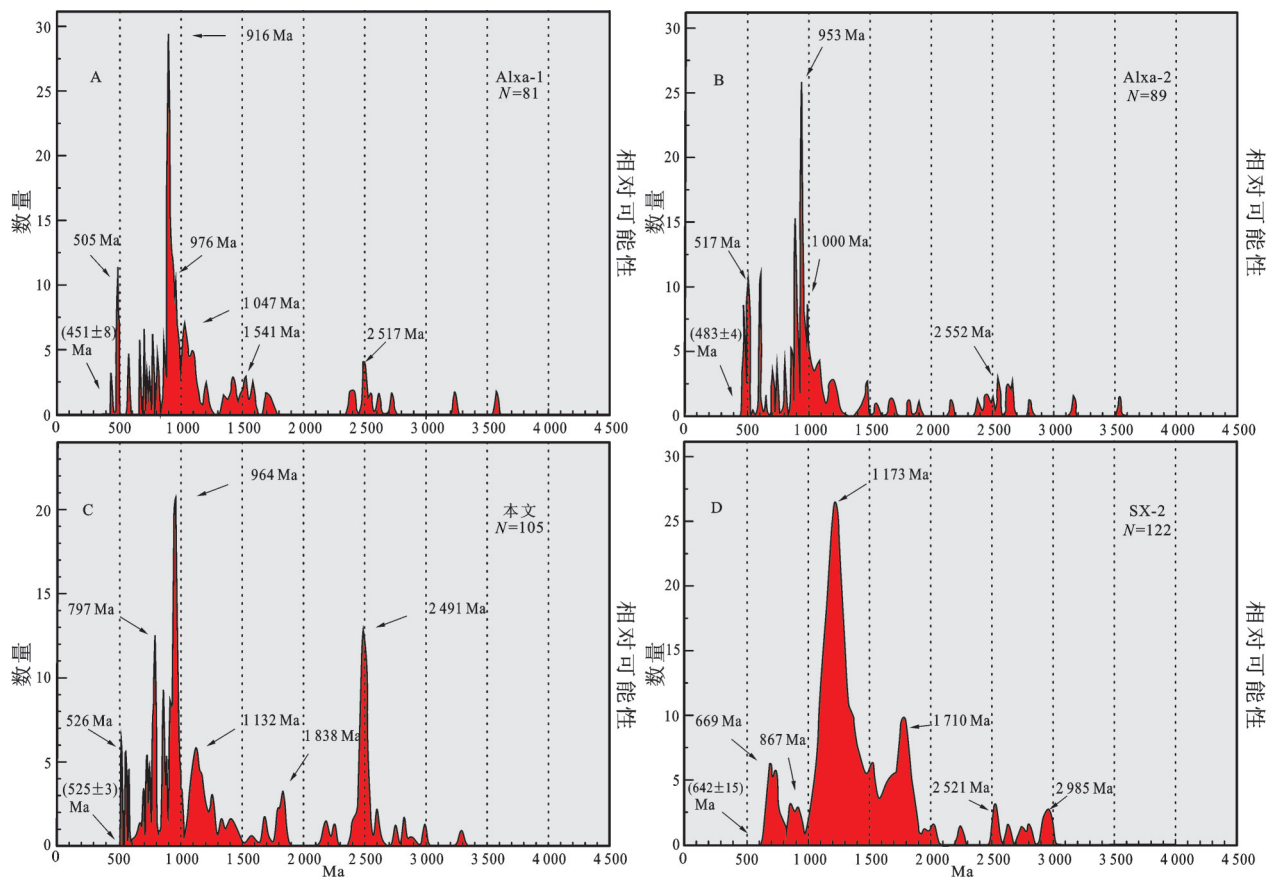


图6 香山群与米钵山组锆石成分对比图

A, B—米钵山组(据文献[13]);C—香山群样品SQ12-01(本文);D—香山群样品SX-2(据文献[40])

Fig. 6 Comparison of zircon constituents between the Xiangshan Group and the Miboshan Formation

A and B—Miboshan Formation [13]; C— Sample SQ12-1 from the Xiangshan Group ( this study); D— Sample SX-2 from the Xiangshan Group (after reference [40])

为黄绿色中细粒砂岩中,地层产状 $230^{\circ}\angle 85^{\circ}$ ,校正后都显示物源来自NEE。G点数据采自大柳树沟徐家圈组,为波状斜层理,地层产状为 $305^{\circ}\angle 65^{\circ}$ ,岩性为灰绿色中细粒砂岩,校正后指向NE方向,可能与前人<sup>[6]</sup>认为的内波与内潮汐有关。H和I点数据均采自于石峴子狼嘴子组,小型斜层理,H点处岩性为灰绿色中细粒砂岩,地层产状 $302^{\circ}\angle 45^{\circ}$ ,数据经过校正后显示古水流来自NEE方向;I点处岩性为灰绿色中细粒砂岩,产状 $292^{\circ}\angle 74^{\circ}$ ,经过校正后显示古水流来自SSE方位。另外,李向东等<sup>[6]</sup>在香山地区徐家圈组也采集到了大量古水流数据(图8)。对现有古水流数据进行分析,虽然部分结果显示古水流来自香山地区的东南部,但是主体古水流方向应该来自研究区NE方向。

香山群在早古生代寒武纪开始沉积,位于阿拉善东南缘的香山地区,阿拉善位于Altaids南侧,晚三叠世前Altaids南部的微陆块和阿拉善发生碰撞<sup>[73]</sup>,碰撞从西部开始并逐渐向东部延续<sup>[74-75]</sup>,在石炭纪—二叠纪—早—中三叠纪以 $44^{\circ}\text{N}, 84^{\circ}\text{E}$ 欧拉极(同时期华北的欧拉极)发生了 $32^{\circ}$ 逆时针旋转<sup>[76]</sup>。现将研究区获得古流向方位进行恢复,进行顺时针旋转约 $32^{\circ}$ 左右,说明物源可能在目前的阿拉善地块的东侧(图8),而不是阿拉善地块本身。前已述及,华北板块也不是香山群的物源,这说明在早古生代,阿拉善地块与华北板块还是彼此分离的,结合相似的碎屑锆石年龄,香山群与西南澳大利亚有很大的亲缘性,我们推测在早古生代早期,阿拉善地块的东侧可能就是西南澳大利亚。

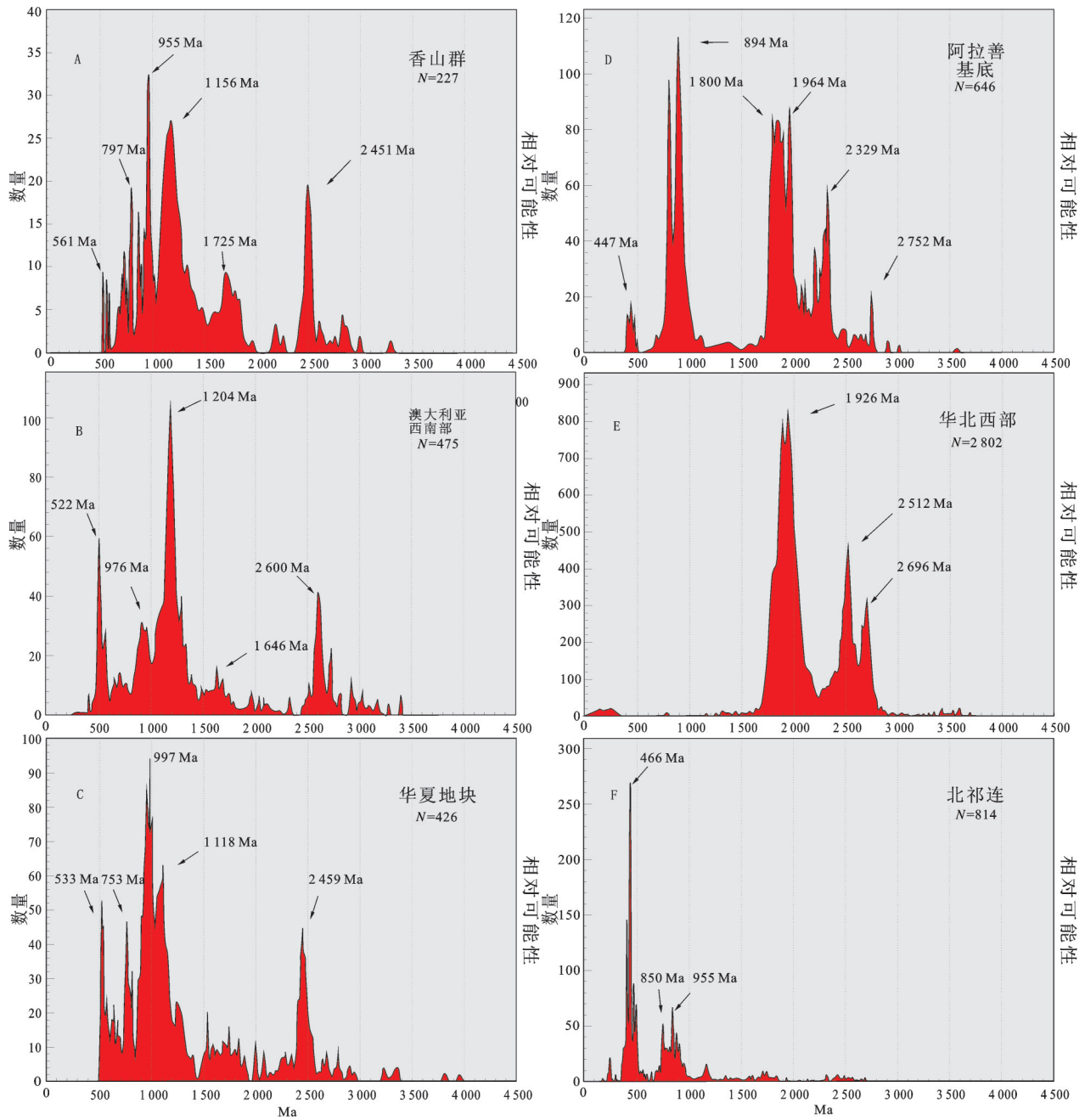


图7 香山群碎屑锆石年龄与阿拉善、北祁连、华北板块及西澳大利亚  
岩浆变质事件锆石年龄对比图

A—香山群(SQ12-1 本文, SX-2 据文献[40]); B—澳大利亚西南部(据文献[45-46]); C—华夏地块(据文献[47]); D—阿拉善基底(据文献[24-26,43-44, 48-55]); E—华北西部(据文献[27,56-64]); F—北祁连(据[41,65-67])

Fig7 Comparison between ages of detrital zircons from the Xiangshan Group and ages of different magmatic and metamorphic events in Alxa, North Qilian, North China Block and Western Australian

A— Xiangshan Group (sample SQ12-1 from this paper and sample SX-2 (after reference [40])); B— Westsouth of Australian (after references [45-46]); C— Cathaysia Block (after reference [47]); D— Basement of Alxa terrane [24-26,43-44, 48-55]; E— Western margin of North China Block (after references [27,56-64]); F— North Qilian Organic Belt (after references [41,65-67])

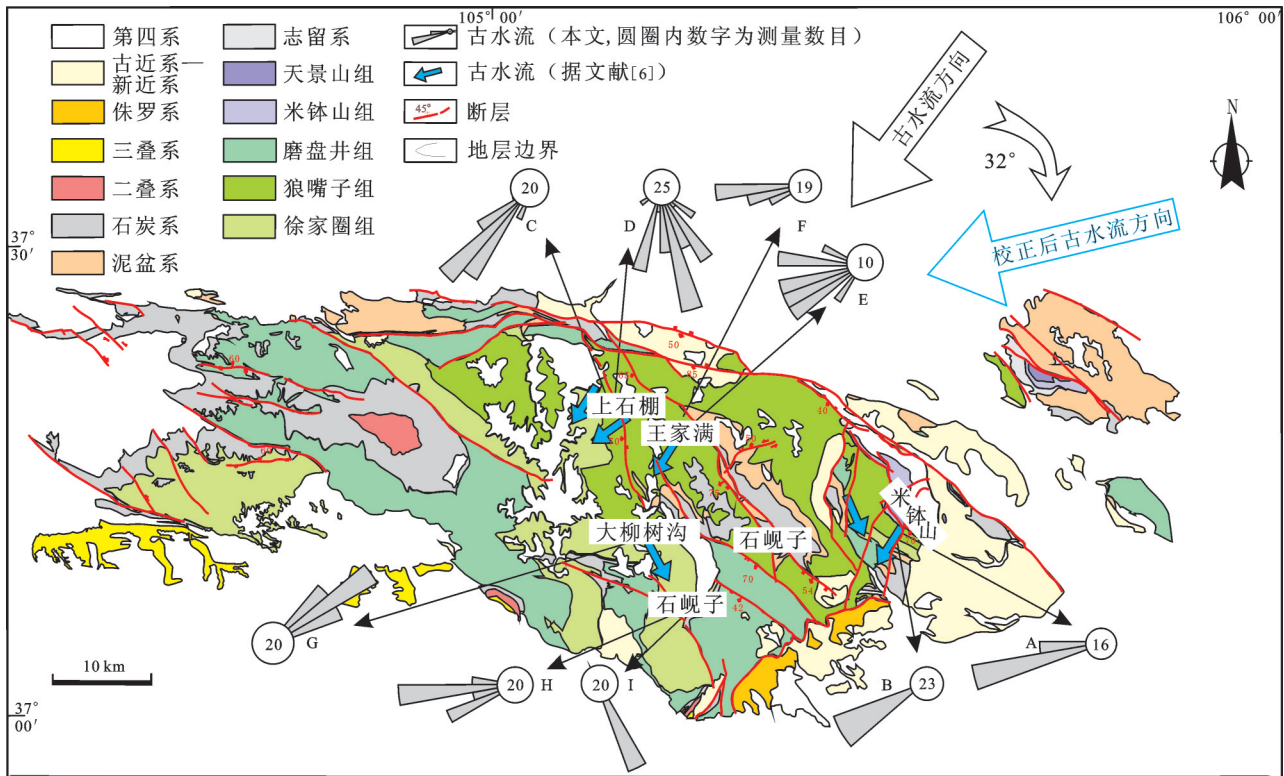


图8 香山群部分古水流采集点及古流向校正结果  
Fig. 8 Distribution of paleocurrents of Xiangshan Group

## 6 结论

结合前人相关研究,通过对河西走廊东部象山区的锆石 LA-ICP-MS 定年以及古流向分析,表明香山群时代应该早于米钵山组,其沉积年龄为中—晚寒武世;华夏地块、阿拉善地块、华北板块和北祁连造山带并不是香山群物源,澳大利亚西南部的岩浆变质事件年龄与香山群年龄数据最为匹配,结合古流向的分析结果,本文认为澳大利亚西南部可能是香山群的物源。

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