王智琳,许德如,MONIKA Agnieszka Kusiak,吴传军,于亮亮. 2015. 海南石碌铁矿独居石的成因类型、化学定年及地质意义. 岩石学报, 31(1): 200-216

海南石碌铁矿独居石的成因类型、化学定年及地质意义

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基金项目：本文受国家自然科学基金项目(41302049、41472171)、国家"973"项目(2012CB416806)和中国科学院矿物学与成矿学重点实验室合作研究基金(KLMM20120102)联合资助.

摘要：

海南石碌铁矿是我国最大的富赤铁矿矿床,同时伴生有钴、铜等多金属矿产。轴向北西-南东向的复式向斜是石碌铁、钴铜矿体的主要控矿构造,富铁矿和钴铜矿的形成与该褶皱变形及伴随的韧性剪切和高温塑性流动有着密切的关系。为获得该构造变形的年代学信息和证实构造变形对成矿物质的富集影响,本文开展了石碌铁矿近矿围岩—石碌群第六层透辉石透闪石岩中独居石的显微结构观察和电子探针化学Th-U-Pb定年(CHIME法)。显微结构观察发现独居石往往沿岩石面理定向分布,且具典型的球冠结构,表现为围绕独居石核部向外依次出现磷灰石、褐帘石、绿帘石同心环。电子探针分析结果表明这些独居石为Ce-La-Nd磷酸盐[(Ce, La, Nd, Th)PO_4],具富钍独居石端元组分。ThO_2含量范围(0.78%~4.61%)、稀土特征以及独居石的产出特征均暗示了其为同构造变质成因。电子探针CHIME化学定年结果表明独居石的年龄变化范围为614~397Ma,并具有两个峰值年龄:即主峰值ca.455Ma和次峰值ca.564Ma。低的ThO_2(0.78%~1.65%),PbO(0.02%~0.04%)和CaO(0.50%~0.97%)含量,以及高的Th/U比值(23.06~53.11)暗示了构成ca.564Ma的独居石是早期剪切变形事件的产物。而在随后剪切变形过程中独居石在低角闪岩相变质条件下以及碱性变质流体诱导下发生了溶解-再沉淀,形成了具ca.455Ma年龄的补丁状成分区。该过程引起了U-Pb体系的局部重置,形成的独居石具有变化较大的ThO_2(0.92%~4.61%)、PbO(0.01%~0.08%)和CaO(0.28%~1.58%)含量范围以及Th/U值(24.83~52.86)。在剪切变形之后,早期变质成因的独居石在绿片岩相退变质作用过程中及富Ca、Fe、Si、Al流体参与的条件下,经不平衡反应形成了磷灰石-褐帘石-绿帘石球冠物,反应机制以独居石和球冠矿物间的元素扩散动力学为主。该反应暗示了REE、Y、Th等元素发生了迁移,并可能引起边部独居石的部分Pb丢失。结合华南的构造演化,年龄谱主峰值455Ma代表了与华南加里东造山运动有关的区域变质和动力变质作用事件年龄,是加里东运动在海南岛的响应;次峰值年龄564Ma对应着冈瓦纳泛非事件,暗示了华南在晚新元古代-早古生代与冈瓦纳大陆具有亲缘性,华南加里东运动引起陆内造山过程可能与冈瓦纳大陆的聚合碰撞事件有关。因此,晚新元古代-早古生代造山事件对海南岛构造演化历史具重要影响。此外,该构造运动使石碌群发生褶皱变形,伴随产生的变质流体使铁、钴铜成矿元素进一步活化和富集,对石碌铁、钴铜矿的富集有着重要影响。

英文摘要：

Shilu iron ore deposit in Hainan Province is the largest hematite-rich deposit in China, associated with cobalt, copper and other polymetallic mineral resources. This deposit is largely hosted within the Neoproterozoic Shilu Group, a suite of low-garde, neritic siliciclastic and carbonate sedimentary succession with generally greenschist (locally up to amphibolite) facies metamorphism. The NWW-trending synclinorium is main ore-controlling structure for iron, cobalt and copper ore bodies in the district. Previous studies suggested that folding and associated ductile shearing and high-temperature plastic flow had played an important role in enrichment of iron, cobalt and copper metals. To confirm this, we carried out in situ analysis on chemical compositions and CHIME (total Th-U-Pb) dating on monazite from the proximal diopside-tremolite rocks in the Shilu Group, using electronic probe microanalysis (EPMA) on thin sections assisted by BSE image. Microscopic observation revealed an alignment of monazite parallel to regional foliation defined by low amphibolite-facies minerals, and that monazite was characterized by typical replacement of breakdown coronas with obviously mineral concentric zoning, i.e., monazite in the core successively ringed by apatite, allanite and epidote tow

ards rims. EPMA analysis suggests that monazite is composed of cerium phosphate ((Ce, La, Nd, Th)PO_4) with cheralite as the main end member. The typical occurrence, ThO_2 contents (ranging from 0.78% to 4.61%) and REE pattern all indicate a metamorphic origin for studied monazite. CHIME dating results show that monazite yields the apparent ages ranging from 397Ma to 614Ma with a main age peak at 455Ma and a subordinate peak at 564Ma. Low contents of ThO_2 (0.78%~1.65%), PbO (0.02%~0.04%) and CaO (0.50%~0.97%), and high ratios of Th/U (23.06~53.11) could interpret monazite with ca.564Ma age as production of the early deformational metamorphic event. Subsequent dissolution-reprecipitation of monazite, during the later shear deformation, caused patchy zonation and chemical alteration of crystallised monazite domains. This process finally reset the U-Th-Pb system by the aids of possible alkali-bearing metamorphic fluid, and yielded the main peak age of ca.455Ma. The patchy domains have variable contents of ThO_2 (0.92%~4.61%), PbO (0.01%~0.08%) and CaO (0.28%~1.58%), and high Th/U ratios (24.83~52.86). The breakdown of monazite to the coronal minerals was most likely related to the process of post-deformational greenschist-facies retrograde metamorphism with the participation of possible Ca-, Fe-, Si-, Al-rich fluids by unbalance reaction. The reactive mechanism is elemental diffusion between monazite and coronas minerals, indicating that the REE, Y, and Th were mobile at a small scale and partial Pb loss may happened in the rim of monazite. In line with the tectonic development of south China, we suggested that the ca.455Ma age likely recorded a regionally metamorphic event corresponding to South China Caledonian orogeny. Whereas the 564Ma age might be linked to Pan-African event, implying that South China had an affinity to Gondwanaland in late Neoproterozoic to early paleozoic. Based on the available age data, the Caledonian event in South China could be considered as the subsequently intracontinental orogeny corresponding to the assembly and collision of Gondwanaland. Therefore, the Late Neoproterozoic to Early Paleozoic orogenic events might play an important role on the tectonic evolution of Hainan Island. Moreover, the orogenic event (s) had great significance for the enrichment of iron, cobalt and copper metals in the Shilu deposit.

关键词：独居石 球冠结构 CHIME年定 华南加里东运动 冈瓦纳大陆 海南石碌铁矿

投稿时间： 2014-02-17 最后修改时间： 2014-04-04

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黔ICP备07002071号-2
主办单位：中国矿物岩石地球化学学会
印刷版(Print): ISSN 1000-0569 网络版（Online）: ISSN 2095-8927
单位地址：北京9825信箱/北京朝阳区北土城西路19号
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