

冈底斯东段驱龙-甲玛矿集区新近纪花岗岩类 区域岩石学及成矿学意义

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摘要:对埃达克岩及其与成矿的关系的研究是近几年花岗岩地质研究的重要进展之一。本文通过对驱龙—甲玛矿集区新近纪花岗岩地质和元素、同位素地球化学综合分析,探讨了新近纪花岗岩类的成因及形成的动力机制、成矿意义。结果表明,新近纪花岗岩具有埃达克岩的地球化学特征,其岩浆起源于下地壳,在上升或演化过程中与幔源岩浆发生了混合,该混合作用对成矿具有重要意义。23~10 Ma 岩石圈伸展导致软流圈上涌并诱发含石榴石镁铁质岩石拆沉,拆沉下地壳部分熔融形成埃达克岩浆。岩浆混合、岩浆流体出溶的地质、矿物学证据以及有利的大地构造背景、深部物质组成、蚀变特征表明驱龙—甲玛矿集区新近纪“似埃达克岩”具非常重要的成矿学意义。

关键词:花岗岩类; 埃达克岩; 成生演化; 地球动力机制; 成矿学意义

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Regional Petrology of Neogene Granitoids in the Qulong-Jiama Ore-concentrated Area of the East Gangdese Belt, Tibet and its Metallogenic Significance

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Abstract: The study of adakites and their roles in mineralization is one of the most important progresses in recent years. On the basis of their geological, chemical and isotope characteristics, this paper studies the genesis and evolution of Neogene granitoids in the Qulong-Jiama ore-concentrated area, and investigates the mechanisms of granitoids and adakites to probe their metallogenic significance. The results show that Neogene granitoids exhibit obvious calc-alkali to adakite evolutional current and adakite feature; diagenetic and ore-forming materials inheriting the features of the island-arc granite; granitoids derive from the lower crust, then mix with EM II during evolution; lithosphere extension which initiated in 23-10 Ma caused upwelling of asthenosphere and delamination of garnet-bearing mafic rocks, partial melting of the delaminated lower crust produced adakites. Considerable geological and mineral evidences of magma mixing and fluid exsolved, favorable geotectonic setting and alteration characteristics demonstrate that Neogene “adakite-like” granitoids in the Qulong-Jiama ore-concentrated area have a great metallogenic significance.

Key words: granitoid; Adakites; genesis and evolution; mechanism of Earth; metallogenic Significance

埃达克岩是指具高 Sr/Y 和 La/Yb 比值、强烈亏损重稀土元素的中酸性岩浆岩, 其可能的成因模式包括: 板片熔融以及板片熔体与地幔的反应^[1]; 幕

源岩浆的分离结晶^[1]; 增厚玄武质下地壳部分熔融^[2,3]。近年研究成果表明, 埃达克质岩与浅成低温热液矿床及斑岩矿床有密切的关系, 斑岩型铜矿

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的斑岩 90%以上可能具有埃达克岩的地球化学特质^[4]。

冈底斯构造岩浆带中-新生代以来经历了复杂的构造岩浆活动,藏南分布的后碰撞超钾质岩浆作用以及埃达克岩,对于了解青藏高原的隆升时限以及东西向伸展具重大意义^[5,6]。冈底斯东段目前已发现众多斑岩-矽卡岩矿床(矿点)^[7~9],其中驱龙-甲玛矿集区是西藏重要的铜钼铅锌矿集区之一,区内与成矿有关的主要为新近纪花岗岩类(17~15 Ma)。本文通过对驱龙-甲玛矿集区新近纪花岗岩地质和元素地球化学分析,探讨其成因及动力学、成矿意义。

1 区域地质背景及典型矿床地质特征

矿集区出露二叠系至第四系地层(图 1A、B)。二叠系洛巴堆组为块状灰岩、碎屑灰岩、细晶灰岩夹泥灰岩。三叠系麦隆岗组主要为灰岩夹泥质灰岩、粉砂岩,但出露面积较小。侏罗系叶巴组分布较广,总体呈东西向展布,向西逐渐尖灭。叶巴组一段凝灰质火山角砾岩、集块岩,二段流纹质晶屑凝灰岩、安山岩、英安岩,三段凝灰质英安岩、凝灰岩;多底沟组块状结晶灰岩夹少量薄层灰岩、泥灰岩。侏罗系却桑温泉组砾岩、长石石英砂岩夹泥侏罗系-白垩系林布宗组泥岩、粉砂岩,夹石英砂岩,砂砾岩。白垩系楚木龙组石英砂岩、含砾石英砂岩,粉砂岩等。古近系-新近系大竹卡组复成分砾岩,砂砾岩。主要岩浆岩包括白垩纪流纹斑岩、安山玢岩、辉绿玢岩,古新世英云闪长岩、石英闪长岩和二长花岗岩,始新世花岗闪长岩、二长花岗岩,渐新世英云闪长岩、花岗闪长斑岩、二长花岗岩,以及中新世花岗斑岩。其中新近纪侵入岩主要为花岗斑岩、花岗闪长斑岩等,呈小岩株、岩滴、岩瘤状零星分布于矿集区内,其侵位高峰期在 15 Ma 左右,岩体与围岩接触界线清楚,岩体边部可见围岩捕虏体,呈棱角状。岩体平面形态不规则,岩体内部组构不发育,具被动就位特征。矿集区以东地段主要褶皱构造为墨竹工卡复式向斜,温区-沃卡韧性剪切带和卡松拉-米拉山逆断裂南北分布,南缘发育北西西向的推覆构造系,主推覆面由被动陆缘期的控盆深断裂反转而成,现在变现为逆掩断层,具有韧-脆性变形特征,是长期演化、多阶段发展而成^[14,15]。

驱龙典型矿床地层主要为叶巴组的一套英安质-流纹质火山岩、火山碎屑沉积夹碳酸盐岩建造,岩体岩石类型主要为二长花岗斑岩、黑云母二长花岗岩。岩体受近东西向的构造控制,矿区裂隙构造

发育并控矿,裂隙主要以陡倾角产出于斑岩体顶部,较缓倾角产于斑岩体的外接触带控制着矿体的分布、产状和规模(图 1C)。矿区中铜矿中辉钼矿 Re-Os 模式年龄为 15.8~16.9 Ma, Re-Os 等时线年龄值为 16.0~16.4 Ma^[12,16~19]。

甲玛典型矿区出露地层主要为下白垩统林布宗组(K_1l)砂板岩、角岩以及上侏罗统多底沟组(J_3d)灰岩、大理岩。矿区岩浆岩种类较多,岩性较杂,包括了花岗斑岩、黑云母二长花岗斑岩、花岗闪长斑岩、石英闪长玢岩、闪长玢岩、闪长岩、闪斜煌斑岩、角闪辉绿(玢)岩、石英辉长岩等基性和中酸性岩(图 1B)。成矿时代 15.2~16.3 Ma, 甲玛铜多金属矿主要矿体为夕卡岩型铜多金属矿体、角岩型铜钼矿体,前者赋存在林布宗组与多底沟组的层间构造中或甲玛-卡军果推覆构造体系中的多底沟组中;后者分布于林布宗组中^[20,21~23]。

帮浦典型矿床出露下二叠统洛巴堆组灰岩、板岩和老第三系古新统典中组中酸性凝灰岩,两者呈断层接触。与成矿有关岩体主要是花岗闪长斑岩、花岗斑岩、二长花岗斑岩、闪长(玢)岩,其次为黑云母二长花岗岩、石英斑岩、辉绿岩脉等。花岗斑岩、花岗闪长斑岩严格控制了矿区的钼(铜)矿体形态与规模,呈岩株状产出,为容矿岩石(图 1D)。成矿时代为 15.3±0.8 Ma^[13,24]。

斑岩型矿床矿化在空间上具有明显的分带性,且矿化分带往往与蚀变分带很好对应。矿集区典型矿床的矿化分带、蚀变分带由内向外、自下而上的特征为:①蚀变分带包括钾硅酸盐化蚀变、石英绢云母化蚀变、青磐岩化蚀变、泥化(粘土化)蚀变,其中泥化发育程度不等;②矿化类型由细脉浸染状铜钼矿化向脉状、细脉状铜铅锌矿化变化;③金属矿物组合黄铜矿-辉钼矿-黄铁矿-磁铁矿-磁黄铁矿-黄铜矿-斑铜矿-黄铁矿、方铅矿-闪锌矿-黄铜矿-黄铁矿;④成矿元素组合由 Cu、Mo 向 Pb、Zn 变化,钾硅酸盐化与成矿关系最密切,稍晚的石英绢云母化蚀变次之^[13,16,22]。

2 花岗岩类成生演化

2.1 常量元素特征

驱龙、甲玛矿床成矿岩石的岩性主要为二长花岗岩,驱龙矿区的少数岩石为钾长花岗岩和花岗闪长岩,甲玛矿区的少数岩石为石英二长花岗岩。岩石为准铝质-过铝质(图 2A),高钾钙碱性-钾玄岩系列(图 2B)。Bea^[25] 等以 4200 个 I、S、M、A 型花岗岩样品的统计分析为基础,分别用主要元素、标准矿

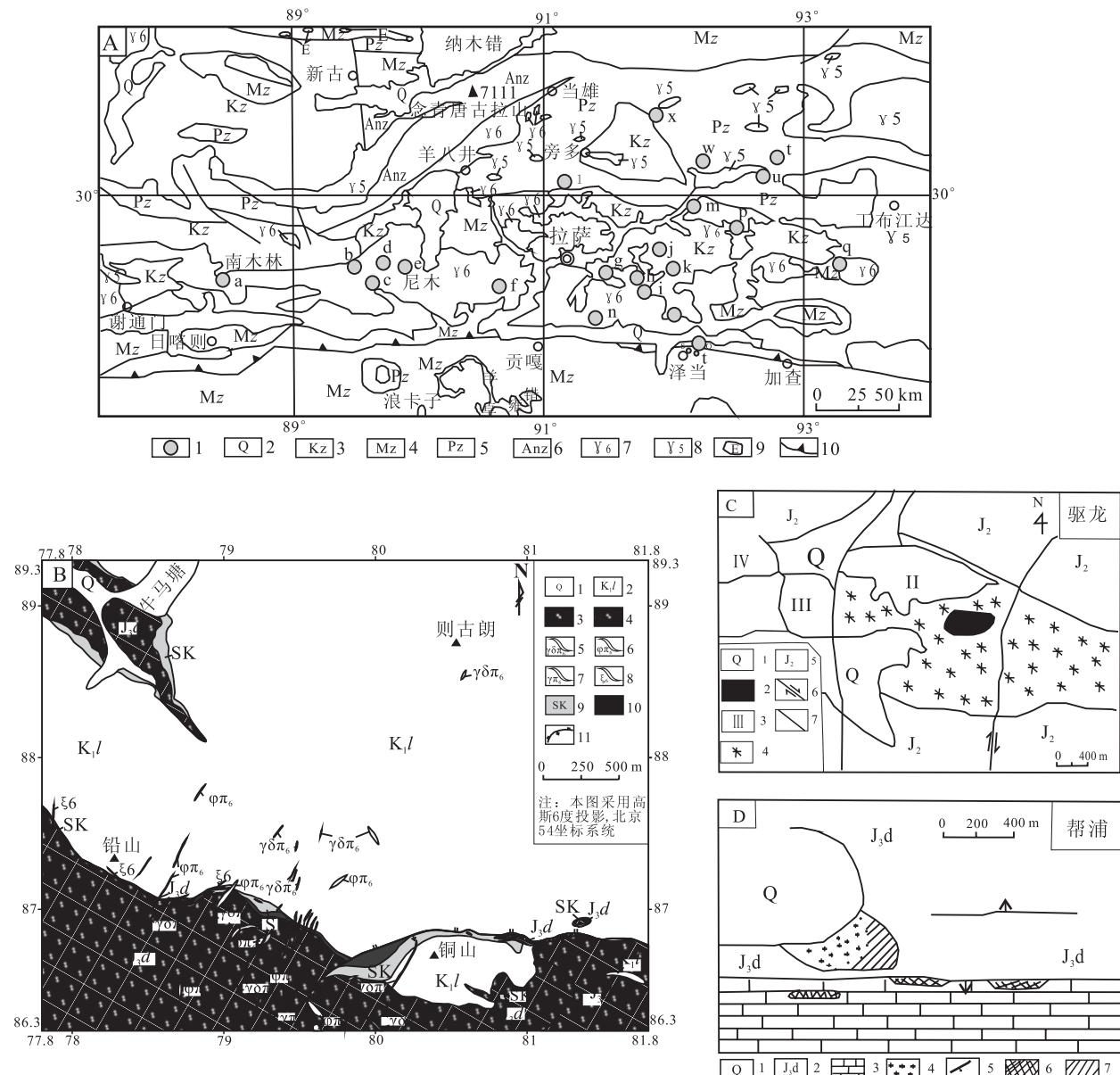


图 A 据[10]修改: 1-矿床(点); 2-第四系; 3-新生代; 4-中生代; 5-古生代; 6-前震旦系; 7-喜马拉雅期花岗岩; 8-燕山期花岗岩; 9-超基性岩; 10-结合带; a-吉如铜矿; b-白容铜矿; c-总训铜矿; d-冲江铜矿; e-厅宫铜矿; f-达布铜矿; g-拉抗俄铜矿; h-驱龙铜(钼)矿; i-知不拉铜多金属矿; j-甲玛铜多金属矿; k-向背山铜矿; l-勒青拉铅锌矿; m-帮浦钼(铜)矿; n-克鲁铜矿; o-冲木达铜矿; p-夏马日铜矿; q-吹败子铜矿; r-明则铜钼钨矿; s-劣布铜钼钨矿; t-亚贵拉铅锌多金属矿; u-沙让钼矿; w-蒙亚啊铅锌矿; x-拉屋铅锌铜矿;

图 B 据[11]修改: 1-第四系; 2-下白垩统林布宗组砂板岩、角岩; 3-上侏罗统多底沟组灰岩、大理岩; 4-矽卡岩化大理岩; 5-喜马拉雅晚期花岗闪长斑岩脉; 6-喜马拉雅晚期石英钠长斑岩脉; 7-喜马拉雅晚期花岗斑岩脉; 8-喜马拉雅晚期细晶岩脉; 9-矽卡岩; 10-矽卡岩型矿体; 11-滑覆构造断裂;

图 C 据[12]修改: 1-第四系; 2-东部二长花岗斑岩; 3-西部斑岩(Ⅱ、Ⅲ及Ⅳ表示原斑岩体编号); 4-荣木错拉复式岩体; 5-叶巴组; 6-SN 向裂隙带; 7-未知性质断层;

图 D 据[13]修改: 1-第四系; 2-多底沟组; 3-二叠系灰岩; 4-花岗斑岩; 5-断层; 6-Cu-Pb-Zn 矿化体; 7-Cu-Mo 矿化体

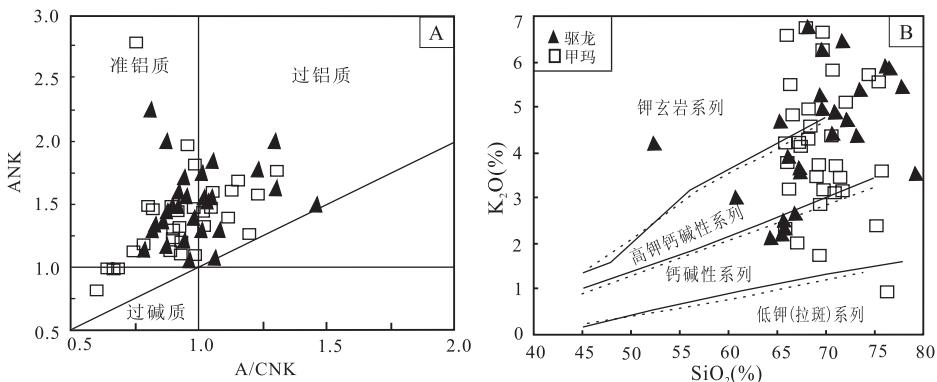
Fig. A modified form [10]; 1-Mineral deposits(mineral occurrence); 2-Quaternary; 3-Cenozoic; 4-Mesozoic; 5- Paleozoic; 6-Presinian system; 7-Himalayan Epoch granitoids; 8-Yanshanian granitoids; 9-Ultrabasic rocks; 10-Junction zone; a-Jiru; b-Bairong; c-Zongxun; d-Chongjiang; e-Tinggong; f-Dabu; g-Lakange; h-Qulong copper (molybdenum) deposit; i-Jihuba polymetallic copper deposit; j-Jiamala polymetallic copper deposit; k-Xiangbeishan; l-Leqinla; m-Bangpu molybdenum (copper) deposit; n-Kelu; o-Chongmuda; p-Xiarima; q-Chuibaizi; r-Mingze copper molybdenum and tungsten deposit; s-Lebu copper molybdenum and tungsten deposit; t-Yaguita polymetallic Lead-Zinc deposit; u-Sharang molybdenum deposit; w-Mengyaa; x-Lawu (a-g, k, n, o, p, q, Copper deposit;l, w, x: Lead-Zinc deposit); Fig. B modified form [11]; 1-Quaternary; 2-K1 1 S and slate and hornfels ; 3-J 3d limestone and marble ; 4-skarnization marble; 5-granodiorite porphyry dike; 6-quartz-albitite dike; 7-granite porphyry dike; 8-fine- grained granite dike; 9-skarn; 10-skarn- type body; 11-decollement fault; Fig. C modified form [12]; 1-Quaternary; 2-East Monzogranite porphyry; 3-West-porphyry (Ⅱ、Ⅲ and Ⅳ refer to former porphyry); 4-Rong mucuola complex; 5-Yeba group; 6-SN fracture; 7-Unknown fault; Fig. D modified form [13]; 1-Quaternary; 2-Duodigou group; 3-Permian limestone; 4-granite porphyry; 5-Fault; 6-Cu-Pb-Zn orebody; 7-Cu-Mo orebody

图 1 冈底斯成矿带东段金属矿床分布图及典型矿床地质图

Fig. 1 Distribution map of Metal deposits in East Gangdese and Geological map of typical ore deposits

物成分和不同的岩石化学参数来检验,最后采用ASI、CAI、KNAI、FeMgI、FD1、FD2等参数来划分出5种花岗岩类型等。驱龙矿区岩石主要为I型花

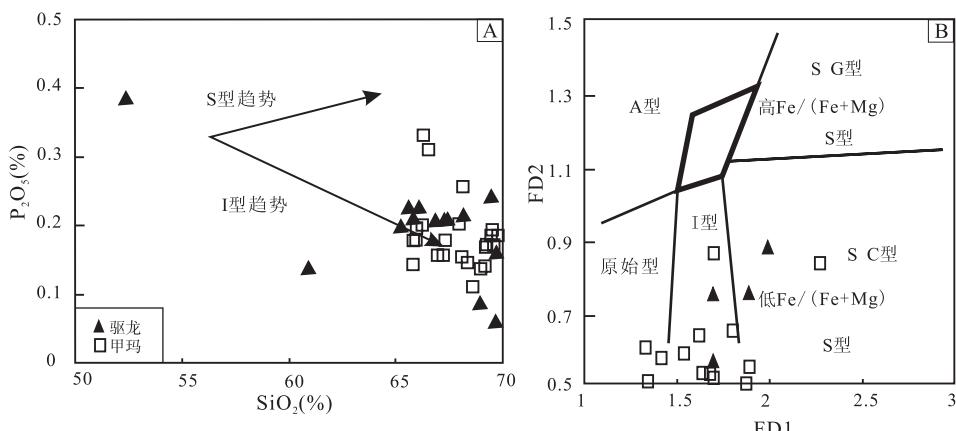
岗岩,而甲玛矿区岩石具I型花岗岩向SC型花岗岩过渡的特征(图3)。



数据来源:[9,13,16,18,19,20,26~29]和部分未公开发表的甲玛数据
Dates from ref. [9,13,16,18,19,20,26~29] some unpublished datas of Jiama

图2 矿集区新近纪花岗岩类 A/NK-A/CNK(A) 和 K₂O-SiO₂(B)

Fig. 2 A/NK-A/CNK and K₂O-SiO₂ diagrams of neogene granitoids of the ore-concentrated Area



ASI=mol. (Al₂O₃/[CaO+Na₂O+K₂O]); CAI=mol. (CaO/[CaO+Na₂O+K₂O]); KNAI=mol. (K₂O/[K₂O+Na₂O]); FeMgI=mol. (FeO/[FeO+MgO]); FD1=10(0.1601 ASI-0.0354 CAI+0.048 KNAI-0.026 FeMgI); FD2=10(0.0061 ASI-0.0434 CAI+0.0145 KNAI+0.1236 FeMgI)

图3 矿集区新近纪花岗岩类型 P₂O₅-SiO₂ 和 FD1-FD2 图(据文献[9,13,16,18,19,20,25~29])

Fig. 3 P₂O₅-SiO₂ and FD1-FD2 diagrams on Neogene granitoid category of the ore-concentrated Area
(modified from ref. [9,13,16,18,19,20,25~29])

2.2 微量元素特征

三个典型矿区成矿岩石总体上表现为轻稀土富集、重稀土元素亏损的右倾平滑曲线,其中驱龙花岗岩类有较明显的Eu亏损,显示斜长石的结晶分异(图4A)。原始地幔标准化的微量元素蛛网图表明,岩石富集大离子亲石元素,尤其是富集Rb、Th、U和K等元素,而亏损高场强元素(如Nb、Ta、P、Ti)(图4B)。Ti亏损可能反映源区有金红石矿物相的残留;K、Rb富集和Ba亏损可能与源区金云母的熔融有关;Sr强烈富集反映岩浆源区可能没有斜长石的残留;Yb亏损则反映岩浆源区有石榴石残留;

Nb、Ta的亏损与Zr、Hf富集表明源区残留相中可能有角闪石的存在^[19]。微量元素特征表明,其源区总体上含金红石、金云母、缺斜长石,残留相中富集石榴子石与角闪石,这样的特征表明岩浆源区可能受到消减作用的影响,继承了岛弧型岩浆岩的部分特征。源区存在不同程度的混源,是由变质杂砂岩、变质玄武岩部分熔融而来^[30]。

2.3 温压条件

Watson 和 Harrison 锆饱和温度计计算公式:
 $\ln D_{\text{Zr}}^{\text{zircon/melt}} = -3.8 - 0.85 \times (M-1) + 12900/T$,
其中 $D_{\text{Zr}}^{\text{zircon/melt}} = 497646 (\times 10^{-6}) / \text{全岩锆含量} (\times$

10^{-6}), $M = (2\text{Ca} + \text{Na} + \text{K}) / (\text{Si} \times \text{Al})^{[30,31]}$ 。驱龙花岗岩类成岩温度为 $647 \sim 800^\circ\text{C}$, 平均 709°C ; 甲玛花岗岩类形成温度为 $657 \sim 799^\circ\text{C}$, 平均 727°C ; 镍石 Ti 饱和温度计求得范围为 $611 \sim 799^\circ\text{C}^{[20,29]}$, 黑云母 Ti 地质温度计算得出的成岩温度为 $600 \sim 800^\circ\text{C}$, 斑岩石英 Ti 地质温度计算得出成岩温度为 $730 \sim 800^\circ\text{C}$ (彭惠娟, 未发表资料); 压力为 $1 \sim 4 \text{ GPa}$ 。

2.4 与埃达克岩对比

矿集区新近纪花岗岩类高硅、高铝、低镁、贫 Y

和 Yb, 与典型埃达克岩相一致, 但其 Sr 含量偏低; 与岛弧埃达克岩相比, 则高钾、低镁、高 $^{87}\text{Sr}/^{86}\text{Sr}$ 、高 $^{207}\text{Pb}/^{204}\text{Pb}$, 低 $^{144}\text{Nd}/^{143}\text{Nd}$ 。这些特征可能暗示其来源、演化较复杂^[32,33]; 与德兴斑岩铜矿相比, Yb_N/MgO 偏低, SiO_2 偏高(图 5), 这种地球化学差异可能与矿集区内岩浆本身存在着由钙碱性向埃达克质岩浆过渡的趋势(图 6)有关, 因而称之为“似埃达克岩”^[20,29]。

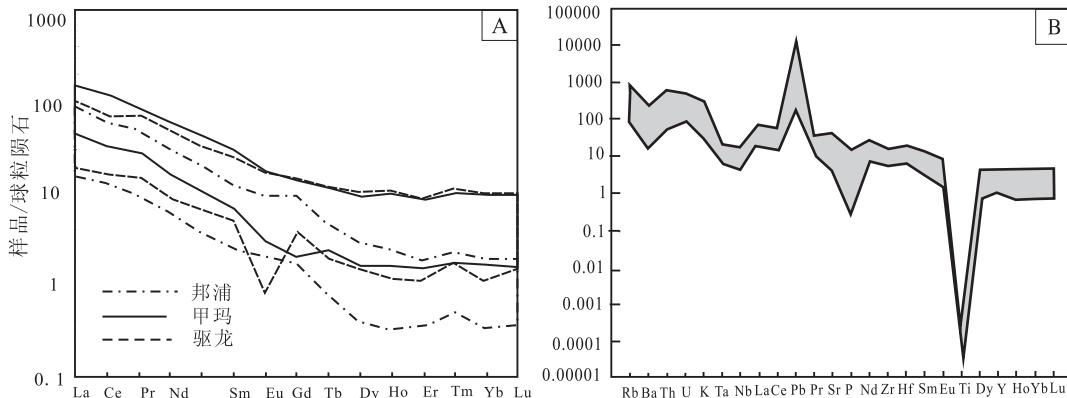


图 4 矿集区新近纪花岗岩类稀土模式图和微量元素蛛网图

Fig. 4 Chondrite-normalized REE distribution patterns and MORB-normalized trace element spidergrams of the neogene granitoid category of the ore-concentrated area

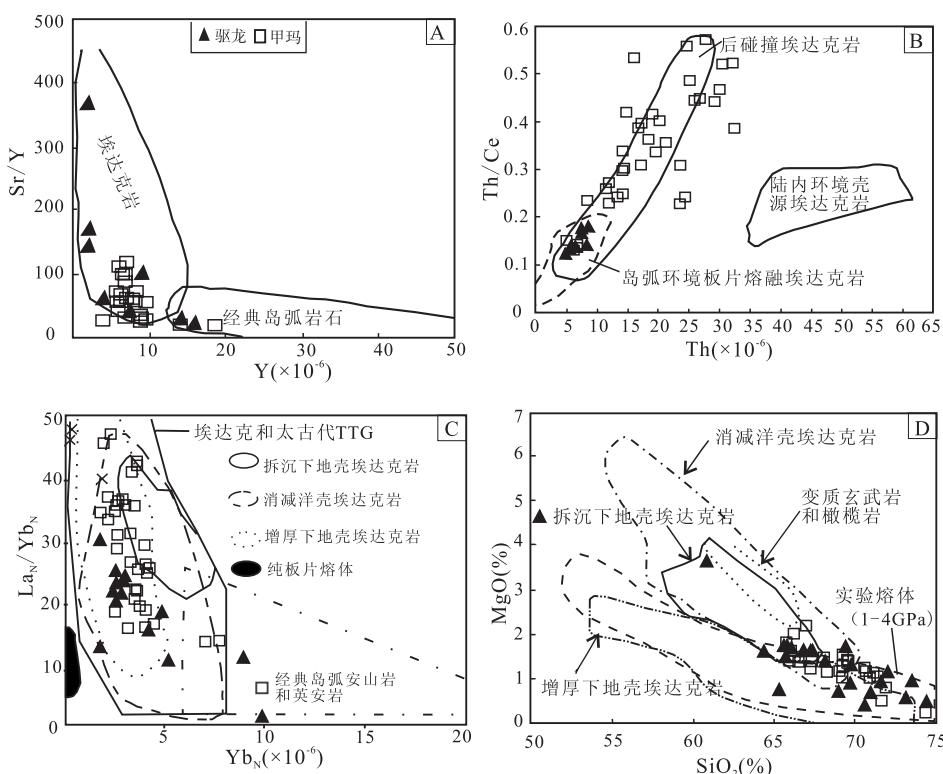


图 5 矿集区埃达克岩成因^[34] (数据来源同图 2)

Fig. 5 Diagrams on adakite genesis of the ore-concentrated area^[34] (date sources are same to Fig. 2)

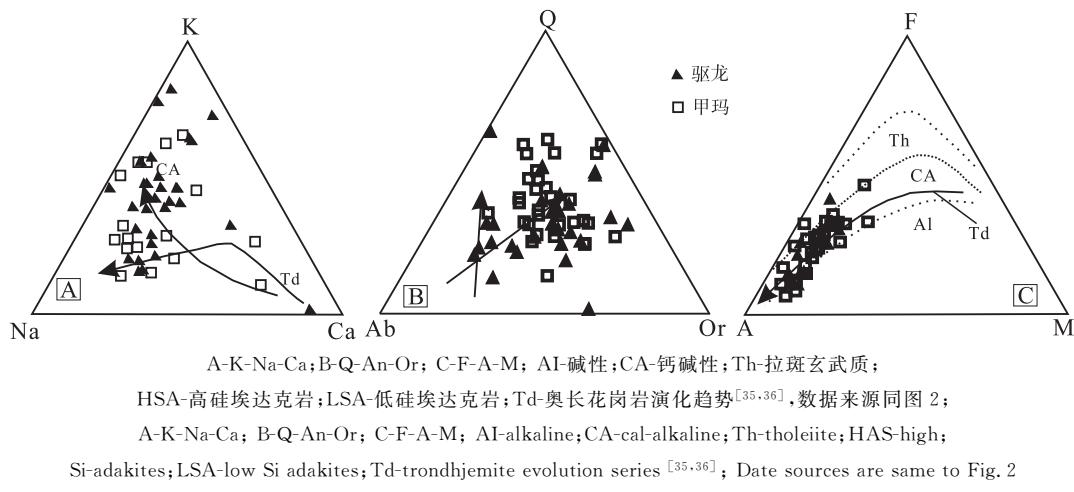


图 6 矿集区花岗岩类演化系列图

Fig. 6 Evolution series of granitoids of the ore-concentrated area

3 花岗岩类及埃达克岩形成的地球动力机制

上述地球化学特征表明,矿集区新近纪花岗岩地球化学特征与埃达克岩浆的地球化学特征(图 6)相似,且存在明显的钙碱性向埃达克质岩浆过渡的趋势。新西兰峡湾白垩世 Darran 岩体记录了这种变化,辉石闪长岩和微闪长岩钙碱性地球化学表明岩浆源于俯冲板片释放流体交代地幔楔熔融而来;而具埃达克特征的石英二长岩,代表了火山弧根部镁铁质、含石榴子石特别是无斜长石的源区^[37]。

青藏高原岩石圈总体表现为地壳厚度大,岩石圈厚度较小,这与岩石圈快速减薄与岩石圈底部拆沉有关^[38],下地壳拆沉代表大陆岩石圈分异的很重要的一个作用^[39],镁铁质地壳在(>40 km, 1.2 GPa)足够的深度石榴子石与残留集合物平衡熔融形成埃达克流体^[40,41]。新近纪埃达克岩最有可能产于拆沉下地壳的部分熔融(图 5)。岩石圈伸展造成地壳的减薄,拆沉导致榴辉质物质从地壳底部拆沉至地幔中,地壳减薄。压力与温度提高可能使下地壳的镁铁质岩石变为含角闪石的榴辉岩,下地壳这种高密度的含石榴石镁铁质岩石拆沉^[34]。

裂谷拉张可能是引起拆沉下地壳部分熔融的诱发因素,区内开始于 23~10 Ma 的裂谷活动,可能诱发了热软流圈地幔沿深部裂谷上涌,从而引发岩石圈地幔拆沉下地壳(含角闪石榴辉岩)脱水部分熔融,所产生的岩浆与地幔橄榄岩反应形成埃达克岩。

4 区域成矿学意义

钙碱性花岗岩向埃达克花岗岩的过渡与斑岩铜

矿的形成密切相关,如智利北部的新生代两套不同时期的岩浆作用:古新世-早始新世钙碱性岩浆铜矿化较低,而具埃达克特征的晚始新世-早渐新世岩体内则发育大型斑岩铜矿。后者同时期无火山作用以及持续的压力形成了封闭体系,阻止了 SO₂ 从埃达克质的、富硫、高氧化状态岩浆中溢出,因而形成大矿;前者同时期火山作用形成开放体系,岩浆去气,成小矿^[42]。图 7 表明矿集区花岗岩类成矿与埃达克岩密切相关。

新近纪花岗岩类中发现大量的镁铁质暗色微粒包体,包体中存在针状磷灰石及暗色黄铁矿化边的眼球状石英,岩浆混合作用明显(苟正彬等未发表资料)。 $\epsilon_{\text{Nd}}(t) < 0$,具富集地幔性质,但甲玛花岗岩较驱龙花岗岩更远离雅鲁藏布江 MORB,靠近 EM II,反映其混合程度不均一(图 8)。结合微量元素、同位素特征,认为矿集区花岗岩类来源于下地壳,在演化过程中与 EM II 存在不同程度混合。斑岩铜矿产于富硫、氧化岩浆环境下,亲铜元素主要以地幔硫化物形式储存。下地壳熔融能否成矿关键在于是否存在渐升的水含量,氧化条件和金属和硫。与新近纪埃达克花岗岩有关的矿化受两个因素限制:地壳厚度和镁铁质下地壳不断提高的氧化条件。压缩体制下南北向构造缩短,地壳厚度不断增厚,地壳基底镁铁质熔体焊接,形成加厚地壳。镁铁质岩浆带来丰富的 Cu 和 S,增厚镁铁质下地壳通过脱水反应进行部分熔融产生含水的富铜岩浆^[43]。

4.1 大地构造背景、深部物质组成对成矿的制约

斑岩型矿床的形成受大地构造背景及成矿环境的制约。17~15 Ma 期间,冈底斯带处于由汇聚造山向伸展走滑转换的后碰撞造山阶段,板片撕裂、断

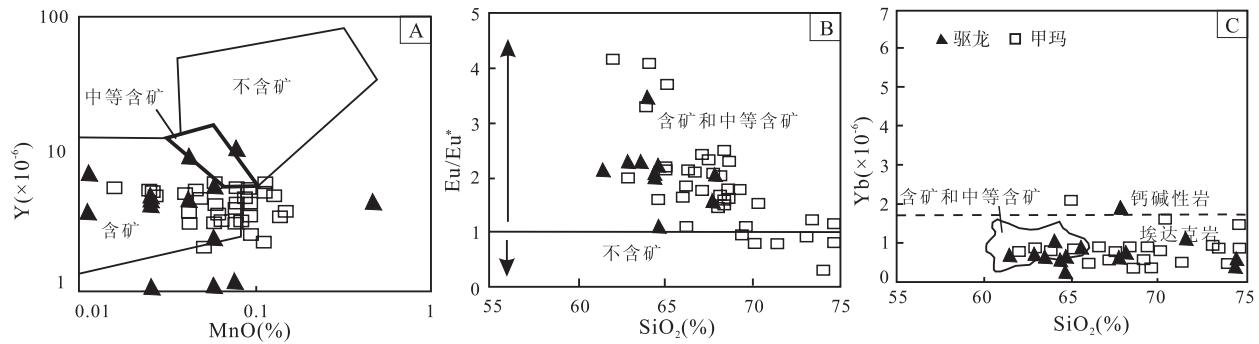


图 7 矿集区新近纪花岗岩类含矿性判别(数据来源同图 2,据文献[43]修改)

Fig. 7 Ore discrimination of Neogene granitoids of the ore-concentration area(same date sources to

Fig. 2; modified from ref. [43])

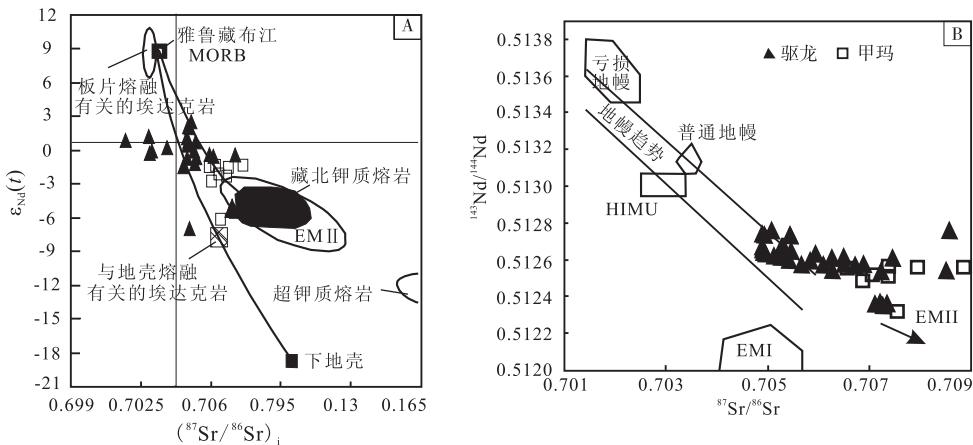


图 8 同位素组成(据文献[18,26,28,29,44])

Fig. 8 Isotopic compositions diagrams(modified from refs. [18,26,28,29,44])

离、岩石圈拆沉导致的软流圈上涌、深部物质减压分熔等因素诱发下地壳或上地幔部分熔融,形成富含挥发分、侵位能力极强的花岗岩浆^[45,46],构造松弛,应力转变,地壳伸展,花岗质岩浆沿南北向伸展构造侵位,驱龙、甲玛、帮浦矿床成带分布。

区域上,布格重力异常自-350~ -550 mg,总体处于由南向北逐渐变低的梯度带上。重力异常等值线主要呈东西向展,局部叠加了一些重力高和重力低异常,显示莫霍面存在北西至南北向的相对重力高和相对重力低带。莫霍面有巨大落差的地带往往与重要的金属成矿带吻合,驱龙、甲玛、帮浦矿区位于相对重力异常高与相对重力低转换部位^[47]。该处异常等值线走向北西梯度极大,三个典型矿床的位置与梯度方向基本一致。布格重力异常的急剧降低,显示存在北西向深断裂,这种构造转换部位为深部岩浆的活动和上升提供了有力条件。

Gotze 等^[48]提出晚奥陶纪-志留纪前安第斯消减带俯冲于智利北部之下相应的残留火山弧形成了安第斯中部的重力高。矿集区位于相对重力高(南西向)与相对重力低(东北向)的转换部位,西南部可

能存在着中生代俯冲残留的岛弧,暗示俯冲的极性自南向北,冈底斯在中生代-新生代早期是岛弧,碰撞成陆后造山阶段的拉张为地幔物质参与成矿提供了通道条件,原本富含成矿物质的岛弧物质也以岩浆混合形式提供成矿物质;驱龙、甲玛矿床自南向北成带排列,俯冲带的距离及地壳的厚度均自南向北增加、增厚,同样佐证了自南向北的俯冲极性。

4.2 成矿岩体的地质地球化学标志

斑岩铜矿床能否成矿很大程度上取决于是否有大量岩浆流体的出溶。岩体顶部有时可留下岩浆出溶的一些记录,如出现大量云英岩、伟晶岩、晶洞构造以及单向固结结构等^[49]。典型矿床岩浆-热液过渡阶段岩浆流体出溶证据有:①地质特征。岩体顶部围岩均发育网脉状破裂隙,则古郎地区发育隐爆角砾岩以及脉宽为0.1~2 m的二长花岗斑岩;晶洞构造、原生晶洞构造发育;林布宗组与多底沟组接触带附近发育岩石的冷凝边和石英边;林布宗组岩体顶部出现细晶岩形成的硅化帽^[23]。帮浦岩体中出现大量石英眼斑,发育隐爆角砾岩,具石英斑晶熔蚀现象,萤石发育(王立强私人通信);②矿物学特

征;驱龙单向固结结构(UST)内的原生包裹体被认为是初始流体出溶的可靠记录^[50],甲玛石英斑晶具有强烈的溶蚀结构,相互连接的显微空腔,斑岩中伴生的萤石以及黑云母和角闪石中的高F含量,斑岩体中流体包裹体与富挥发分熔融包裹体共存等^[51]。

以上证据表明,典型矿床斑岩体富含水,晚期富F,成矿流体更容易形成。另外,岩浆热液生命周期长,年龄跨度达5.7 Ma;深部岩浆房岩浆演化—释放流体—成矿流体演化经历了长期、多阶段、连续的过程,为准备了丰富的成矿物质(朱斯豹等未发表资料)。

4.3 蚀变特征

交代蚀变是岩浆晚期流体饱和出溶以及岩浆期

后流体活动的重要标志,对于判别成矿有重要意义。矿集区新近纪花岗岩类蚀变发育,以钾化、青磐岩化、绿泥石化、矽卡岩化、角岩化、绢云母化、硅化、大理岩化为主,碳酸盐化和泥化为后期蚀变,晚期蚀变往往叠加改造早期蚀变(图9)。钾长石化及其有关蚀变岩与成矿关系最密切,与成矿岩体的成矿专属性关系显著,是中酸性浅成和超浅成斑岩铜、钼、金矿的极重要找矿标志,垂向上具分带性,可能为高钾钙碱性和钾玄岩(图2B)中高钾含量的来源之一;青磐岩化和绿泥石化是中-低温热液矿床的重要蚀变之一,分布于斑岩铜钼矿的外围和顶部^[53]。

矿集区中生代三叠纪麦隆岗组、侏罗纪叶巴组、多底沟组、二叠纪洛巴堆组等地层发育有利于矽卡

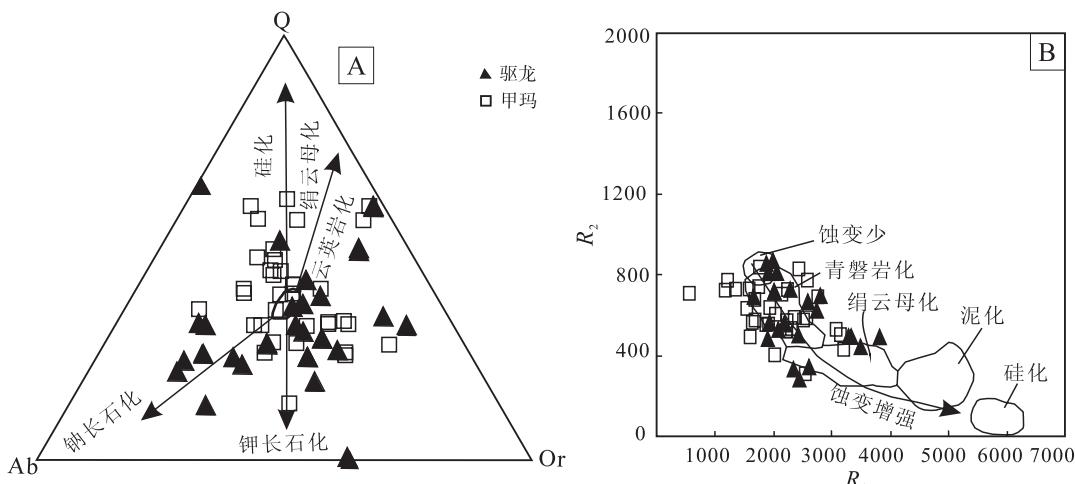


图9 矿集区新近纪花岗岩类蚀变图^[52](数据来源同图2)

Fig. 9 Alteration diagram of Neogene granitoids in the ore-concentrated area^[52] (data sources are same to Fig. 2)

岩形成的灰岩、泥灰岩层,岩体接触带、层间破碎带或推滑覆带等容矿构造发育,因而寻找同期岩浆热液系统有关的矽卡岩型铅锌矿、铜-铅-锌多金属矿、斑岩-矽卡岩复合型铜多金属矿、浅成低温热液型铜-金矿等有重大意义。

5 结 论

(1)新近纪花岗岩类与典型的埃达克岩类似但有不同之处,具钙碱性向埃达克质岩浆演化的趋势,成岩成矿物质明显继承了岛弧花岗岩的特征,称之为似埃达克岩。

(2)岩石圈拉张地壳减薄,含石榴子石镁铁质岩石拆沉,23~10 Ma的裂谷拉张引起拆沉下地壳部分熔融,产生埃达克岩。

(3)岩浆混合、岩浆流体出溶的地质、矿物学证据以及有利的大地构造背景、深部物质组成和蚀变特征表明矿集区新生代“似埃达克岩”具有很好的找

矿前景。

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