· 专题讨论 ·

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中国埃达克岩或埃达克质岩及相关金属成矿作用

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摘　要：本文概述了近年(2003～2006)来中国埃达克岩或埃达克质岩及相关金属成矿作用研究的一些主要进展，主要包括岩石的分布、分类、构造背景、成因，以及一些相关的岩石组合、成矿、实验岩石学和动力学意义等。

关　键　词：埃达克岩；俯冲；拆沉；底侵；铜金矿化；中国

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Adakites or Adakitic Rocks and Associated Metal Metallogenesis in China

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Abstract: Some main advances of the studies on adakites or adakitic rocks and associated metal metallogenesis in China in recent years (during 2003～2006) have been briefly summarized in this paper. They include the distribution, classifications, tectonic setting, and petrogenesis of adakites or adakitic rocks, and their associated rock suites, metallogenesis, experimental petrology and important geodynamic implications.

Key words: adakite; subduction; delamination; underplating; copper-gold mineraliztion; China

埃达克岩最早于1990年由 Defant 和 Drummond[1]提出，我国学者2000年才开始关注埃达克岩的研究，发表了许多有关的文章[2～4]；2003～2006年，他们在埃达克质岩及其与铜-金成矿作用的研究方面取得了许多重要进展。

1　相关术语及分类

1.1　术语

埃达克岩最初是指由俯冲板片部分熔融形成的一套富钠的中酸性火成岩[1]，其主要地球化学特征为：$SiO_2 \geqslant 56$ %，$Al_2O_3 \geqslant 15\%$(很少低于此值)，Y 和 HREE 含量低于正常岛弧火山岩(如 $Y \leqslant 18 \times 10^{-6}$，$Yb \leqslant 1.9 \times 10$)，但具有较高的 Sr(很少小于 400×10)，以及 Sr/Y($\geqslant 40$)、La/Yb($\geqslant 20$)值，暗示石榴子石在其源区作为残留矿物相存在。

张旗等[5～7]认为埃达克岩为一套中酸性火成岩，其特征为亏损 HREE，且没有负 Eu 异常，表明应来自一个较深的、石榴子石稳定残留相的源区；他们将埃达克岩分为 O 型和 C 型：前者富钠，成因与俯冲作用有关，C 型则富钾(大多数的钠含量仍然较高)，为玄武质岩浆底侵引发的加厚下地壳部分熔融的产物。王强等[8]也将其分为两种不同成因的类型：Ⅰ型由俯冲年轻($\leqslant$25～30 Ma)板片熔融形成，Ⅱ型由增厚玄武质下地壳熔融形成。Chung 等[9]和翟明国[10]把由增厚下地壳熔融形成的中酸性火成岩称为埃达克岩。Gao 等[11]把由拆沉下地壳熔融形成的中酸性火成岩称为埃达克岩。董申保等[12]和 Niu[13]则强调，仅仅岛弧区由俯冲洋壳熔融形成的中酸性火成岩才能称为埃达克岩。

许多学者[14～20]指出，由增厚(或拆沉)榴辉质下

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地壳熔融形成的中酸性火成岩由于具与板片熔融形成的埃达克岩类似的元素地球化学特征，也可以称为埃达克岩或埃达克质岩。他们认为，不管是岛弧还是非岛弧环境环境，只要中酸性火成岩具有与俯冲板片熔融形成的埃达克岩类似的地球化学特征，就可以称为埃达克(质)岩[21~38]。

1.2 其它分类

除了O型和C型，张旗等[39,40]把埃达克岩分为六类：1)典型的埃达克岩：由俯冲的拉斑玄武岩或MORB熔融而成；2)高镁安山岩：具高 $Mg^{\#}$ 和Cr、Ni含量为特征；3)TTG系列：以高Si低Mg为特征；4)高钾钙碱性埃达克岩：具高K(Na_2O/K_2O接近1)、低Mg、Cr和Ni的特征；5)高钾高镁埃达克岩(HKMA)；6)超钾质埃达克岩：K/Na>1。李承东等[41]和张旗等[40]根据Sr和Yb的含量，将中酸性花岗岩类分为五类：1)高Sr低Yb型(Sr>400×10，Yb<2×10)，其地球化学特征类似于埃达克岩；2)低Sr低Yb型(Sr<400×10，Yb<2×10)；3)低Sr高Yb型(Sr<400×10，Yb>2×10)；4)高Sr高Yb型(Sr>400×10，Yb>2×10)；5)非常低Sr高Yb型(Sr<100×10，Yb= 2×10～18×10)。

2 中国埃达克(质)岩的时空分布

除广东、广西、湖南和贵州四省(区)[7]外，中国绝大多数地区都分布有埃达克质岩，主要位于太平洋板块和亚洲板块碰撞带、秦岭-祁连山-昆仑山造山带、青藏及中国东部地区[9,15~18,21~31,33~38,42~129]。

其时代为晚太古代(2.5 Ga)到中新世(约10 Ma)。最老的埃达克质岩见于五台杂岩体，为晚太古代(2.5 Ga)[101]。最年轻的出现于青藏[9]。早元古代埃达克质岩分布在江西的东北部[56,57]、秦岭造山带[70]和四川西部[126]。古生代埃达克(质)岩主要分布在中亚造山带[58,59,78,80,81,88,94]，古生代一早中生代的埃达克(质)岩主要出现在秦岭-祁连山-昆仑山造山带[53,72,82,112]。新生代埃达克质岩主要见于青藏[9,23~29,54,55,74~76,84]。最近，青藏北缘和东缘也有三叠纪埃达克质岩的报道[111,113]。中国东部的埃达克质岩主要形成于晚中生代[5~8,10,11,14~19,36,42,43,65~67,85~87,89~93,96,106]。

3 中国埃达克(质)岩的成因

3.1 构造环境和岩石组合

3.1.1 岛弧环境

(1)埃达克岩-高镁安山岩-富铌玄武质岩组合：新疆天山北部地区有与该区巴音沟蛇绿岩同时代的石炭纪埃达克岩-高镁安山岩-富Nb玄武质岩石组合(如阿拉套、喇嘛苏、果子沟、阿希、巴伦台-骆驼沟、土屋-延东和赤湖等)[88,94,95]，可能是俯冲的年轻且热的洋壳熔融产生的熔体交代地幔后形成的岛弧岩浆组合。准噶尔北部的泥盆纪埃达克岩-富Nb玄武岩石组合则可能与古亚洲洋俯冲有关[114,115]。赞岐岩可能与岛弧环境下的埃达克岩有成因联系[130,131]。

(2)埃达克岩-蛇绿岩或洋中脊玄武岩：江西东北部与同时代蛇绿岩共生的新元古埃达克质钠长花岗岩不是先前所认为的由海底扩展、洋壳剪切以及大洋岩石圈碎片的仰冲所致，而是由大洋岩石圈的俯冲所形成[56,57]。内蒙古图林凯蛇绿岩中的埃达克岩是温都尔庙-图林凯早古生代消减带的一种岩浆岩标志[52,59]。华北克拉通的五台组基性-中性-酸性火成岩组成的晚太古代绿片岩属于洋中脊玄武岩-弧-弧后玄武岩-埃达克岩组合[101]。

(3)埃达克岩：中国学者认为大多数埃达克岩产自岛弧环境，不与同时代的玄武岩或高镁安山岩共生[7,70,77,78,80,104,107,119,122,126~128]。

3.1.2 陆内伸展/挤压环境

有人认为中国东部的大多数埃达克岩与俯冲无关[7]。华北克拉通兴隆沟晚侏罗世高镁安山岩-英安岩-埃达克岩也并非在俯冲环境产生[11]。华北克拉通燕山活动地区埃达克质岩形成于190～80 Ma，但高峰期与170～130 Ma的地壳挤压活动一致[19]。

根据中国东南部晚中生代A型花岗岩、板内基性岩、诸多断裂盆地和变质核杂带(如庐山和武功山)的分布，人们认为扬子板块晚中生代埃达克质岩产于陆内伸展的构造背景[16,85,87,89,90]。庐枞地区(扬子地块东部)的埃达克质岩和钾玄岩可能代表了陆内伸展的构造背景[85]，与岛弧环境形成的类似岩石组合不同[1,132,133]。但也有人认为扬子地块东部在早白垩世早期处于大陆边缘岩浆弧内陆一侧，岩浆活动与古太平洋板块的斜向俯冲作用有关[99]；赣南的白垩纪埃达克质岩与晚中生代的岩石圈伸展和玄武质岩浆底侵有关[105]。

3.1.3 同碰撞环境

祁连造山带东南角的关山三叠纪(229±7 Ma)埃达克质花岗岩可能与华北地块和华南地块在三叠期陆陆碰撞有关[112]。

3.1.4 后碰撞环境

青藏高原新生代埃达克质岩一般晚于欧亚板块和印度板块初始碰撞的时期(70～55Ma)，被认为是后碰撞环境的产物[9,23,27,47,48,74~76,84,108]。

3.1.5 造山带伸展垮塌环境

大别造山带北部的

早白垩世埃达克质花岗岩与同期的北大别变质核杂岩密切共生，可能属于造山带伸展垮塌环境[85]。

3.2 岩石成因

3.2.1 俯冲洋壳的部分熔融 大部分埃达克(质)岩被认为是俯冲洋壳部分熔融的产物[12,52,56,57,59,69,70,77,78,88,94,95,103,104,114,115]。江西东北部的埃达克质花岗岩是俯冲洋壳在角闪石+石榴子石稳定区低度熔融形成的[56,57]。五台晚太古代洋中脊玄武岩-弧-弧后玄武岩-埃达克岩组合可能与类似洋中脊玄武岩的熔体和俯冲成因的熔体相互混合有关，而洋内俯冲和与弧后盆地伸展有关的 MORB 型地幔上涌能解释这两种组分的出现[101]。

研究表明，天山北部地区石炭纪埃达克岩-高镁安山岩-富铌玄武质岩组合可能是“埃达克质岩浆交代的岛弧岩浆岩系列”。埃达克岩最有可能由石炭纪北天山洋的年轻洋壳在俯冲过程熔融而成，高镁安山岩可能是板片熔体与地幔楔橄榄岩相互作用的结果，富铌玄武可能是俯冲板片熔体与少量流体交代的地幔楔橄榄岩熔融产物[88,94,95]。北天山早石炭纪的土屋-延东埃达克型斑岩是俯冲大洋板片的部分熔融产物[50,121]。准噶尔北部早泥盆纪埃达克岩-富铌玄武岩的形成与古亚洲洋向南俯冲有关，埃达克岩由俯冲的大洋玄武岩板片部分熔融而成，富铌玄武岩来源于受埃达克质熔体交代的地幔楔的部分熔融[114,115]。

3.2.2 滞留洋壳的部分熔融 尽管西藏东部和南部的新生代埃达克岩形成于后碰撞环境，但有人认为它们产于老的(白垩纪前或白垩纪)滞留洋壳。侯增谦等[24]认为，青藏高原碰撞造山带俯冲并堆积于地幔岩石圈的古老洋壳物质的变质和拆沉，诱发了榴辉岩部分熔融，从而产生埃达克质熔体。高永丰等[23,48]认为西藏南部的中新世埃达克岩是滞留洋壳在后碰撞阶段部分熔融的产物，熔体在上升过程中与上覆交代地幔楔发生作用，使岩浆中 K 含量明显增高。通过对冈底斯铜矿带甲马、拉抗俄、南木、厅宫、冲江及洞嘎 6 个矿区含矿斑岩的全岩 Nd、Sr、Pb、O 同位素分析，曲晓明等[74,76]指出这些中新世含矿斑岩主要是白垩纪一古近纪俯冲到深部的雅鲁藏布江洋壳在榴辉岩相条件下的部分熔融产物，同时有少量俯冲沉积物参与了源区混合。

考虑到江西东北部德兴的中侏罗世埃达克质斑岩和新元古(约 1000 Ma)蛇绿岩套空间上的密切关系和铌同位素的相似，Wang 等[90]指出，除拆沉的下地壳熔融外，其他机制(如残留在地幔的新元古俯冲洋壳的部分熔融)也可能产生这种斑岩。根据主、微量元素和 Nd-Sr-Pb 同位素地球化学研究，李伍平[134]认为辽西北票早侏罗世兴隆沟组埃达克质火山岩可能是古亚洲洋壳残片部分熔融的产物，熔体在上升过程中与地幔楔发生过强烈的混染作用。

3.2.3 增厚下地壳的部分熔融 大部分出现在陆内伸展/挤压、后碰撞和造山带伸展垮塌环境的埃达克质岩是由加厚下地壳的部分熔融所致[5~10,14~16,21,22,26,28,42,43,54,84,86,96]。值得注意的是，青藏高原新生代埃达克质岩也被认为是由榴辉岩质的下地壳部分熔融而成[7,9,26]。一些岛弧环境的埃达克质岩被认为与弧陆碰撞所导致的增厚下地壳熔融或玄武质岩浆底侵有关[53,58,109]。

3.2.4 拆沉下地壳的部分熔融 一些学者认为，扬子板块东部宁镇地区的早白垩世埃达克质岩浆是由拆沉进入到下伏岩石圈地幔中的下地壳部分熔融而成[17]。而华北地块兴隆沟地区的晚侏罗纪高镁埃达克质安山岩是由古老基性下地壳拆沉进入软流圈地幔后部分熔融产生的熔体与地幔橄榄岩相互作用的结果[11]。不少人都认为一些高镁安山岩或埃达克岩是拆沉的下地壳的部分熔融所致[32,36,97,135]。扬子板块东部的一些埃达克质岩石则是榴辉岩质的下地壳拆沉进入下伏热的和更塑性的岩石圈或软流圈地幔中后发生部分熔融所致[85,87,89,90,93]。

3.2.5 岩浆混合 扬子地块东部铜陵地区晚中生代一些中酸性侵入岩的地球化学特征表现出与埃达克岩相似的特点，如高的 Na_2O、Al_2O_3、Sr 含量和 Sr/Y 和 La/Yb 值，但其同位素迥异，如低的 $\varepsilon_{Nd}(t)$ (−9.16～−16.55) 和高的 $(^{87}Sr/^{86}Sr)_i$ (0.7068～0.7105)，且某些样品相对埃达克岩具有高的 Y 和 Yb 含量，很可能是幔源橄榄玄粗质岩浆和增厚玄武质下地壳岩浆混合作用的产物[15]。

3.2.6 富集岩石圈地幔的熔融 西藏东部玉龙二长花岗岩具有某些埃达克岩特征(如高 SiO_2 和 Al_2O_3，低 MgO 含量，亏损 Y 和 Yb，但富集 Sr、Sr/Y 和 La/Yb 值，以及没有 Eu 异常)，可能直接由富集岩石圈地幔的部分熔融而成[136]。也有学者认为西藏南部古近纪-新近纪埃达克质岩是板片熔体交代的上地幔熔融产物[47]。

3.2.7 地壳的同化混染和分离结晶作用(AFC)或分离结晶作用(FC) 有学者认为长江中下游白垩纪埃达克质岩是玄武岩经 AFC 过程而成[99]；晚侏罗世一早白垩世埃达克质岩是富集地幔来源的岩浆经 FC 作用的产物[137]。

3.3 实验岩石学对岩石成因的制约

一些学者为了探讨中国埃达克质岩的成因，总

结了前人的实验资料，指出中国某些高钾(相对板片来源的埃达克岩)的埃达克质岩可能源自高压熔融(1.5～4.0 GPa)或者 K_2O 含量高的变质玄武岩或榴辉岩的熔融[91]。有研究者认为控制埃达克质岩的关键是源岩、水和地壳热结构，中国中部晚中生代富钾高 Sr/Y 值花岗岩类形成于地壳从挤压向伸展转换的环境，可能由底侵的富碱玄武岩在 1.0～1.5 GPa 和 850～1080℃条件下发生部分熔融而成，残留相为辉石岩类[138]。

加了 2%或 5%水的玄武岩在 1.0～2.5 GPa 和 900～1100°C 条件下的熔融实验[139,140]发现金红石在含水玄武岩的部分熔融过程中稳定的压力下限为 1.5GPa，主要受控于水的含量和全岩成分(尤其是 TiO_2 和 K_2O)，证明 Nb 和 Ta 的分配系数 D_{Nb} 和 D_{Ta} 随水含量的增加而减小，随着温度的降低而升高。有人认为金红石是控制太古宙 TTG 熔体 Nb-Ta 的负异常所必须的残留相[139]。根据金红石出现的最小压力(1.5 GPa)，推测俯冲洋壳熔融形成的 TTG 的深度超过 45～50 km [139,140]。

研究表明，新生代埃达克岩的 Na_2O 含量低于 5.8%，大约 95%的新生代埃达克岩样品的 Na_2O 含量小于 5.0%[141]。然而，在埃达克岩产生的压力范围(1.5～3.0 GPa)内，实验的玄武岩部分熔体大多数 Na_2O 含量超过 5.0%，最高达到 9.0%，这表明埃达克岩有明显的 Na 亏损现象。他们认为这是埃达克熔体在热的地幔楔中与地幔橄榄岩反应的结果。在俯冲带，大洋板片熔融产生的埃达克熔体上升并与地幔橄榄岩发生反应，原始的埃达克熔体获得 MgO、CaO、Cr 及 Ni 等地幔组分，但 Na_2O、SiO_2(还可能有 K_2O 等)通过反应进入地幔，导致地幔交代作用。根据长英质熔体与橄榄岩反应体系的相关系，他们认为，在适当的温压条件下地幔单斜辉石、橄榄石、尖晶石的混染作用以及钠质角闪石和斜方辉石的分离结晶作用，是改变埃达克熔体组成并导致 Na 亏损的一个重要的过程。

4 成矿作用

4.1 相关的金属矿化点的空间分布

近年国内有许多与埃达克(质)岩有关的铜金矿成矿作用的报导[7,8,14～16,24～27,34,45,81,82,85,87,90,91,95,104,107,116～121,128,142～148]，将金、铜和银矿床[147,148]分为产于造山带和陆块内两大类，再细分为若干成矿带(区)和亚带(区)。造山带的成矿带有古亚洲洋、秦祁昆、环太平洋和新特提斯，陆内成矿则有中国东部、青藏高原、藏东南-川西南-滇西北等成矿带。

4.2 埃达克(质)岩成矿制约因素

已有研究表明，制约埃达克(质)岩成矿的关键因素在于角闪岩相向榴辉岩相转变过程发生脱水产生埃达克质岩浆，同时萃取地幔中的成矿元素进入岩浆[147]；埃达克(质)岩与埃达克岩类岩石(如高镁安山岩、镁质安山岩、富铌玄武岩和高铌玄武岩等)是多数斑岩型铜矿的容矿岩，也是许多浅成热液矿化系统的成矿母岩，成因上的联系可能在于埃达克质岩浆的富流体、高氧逸度和基性源岩等特征，有利于 Cu、Au 等深源金属元素的萃取与富集成矿[142]。

藏南冈底斯斑岩铜钼成矿系统(13.6～16.9 Ma)与同期埃达克质斑岩(14.5～17.6 Ma)发育于大陆后碰撞地壳伸展环境，来自深部亏损地幔物质与下地壳物质的交换，不仅导致冈底斯加厚、下地壳熔融，而且提供了巨量金属。同时，在下地壳石榴角闪岩部分熔融过程中，残留相由角闪石向石榴子石大规模转变导致角闪石的大量分解，释放出大量流体，是埃达克岩和斑岩铜成矿系统的主导因素[25]。然而另有观点认为，冈底斯斑岩铜矿与雅鲁藏布俯冲板片及其上的少量洋壳沉积物混合物质部分熔融有关[74～76]，或与板片熔体和上地幔源区的交代作用有关[47]。

研究表明，碰撞前的 B 型俯冲和碰撞后的 A 型俯冲相关的斑岩铜矿形成过程中，洋壳或上地幔物质的参与至关重要，含矿斑岩和埃达克岩可能是俯冲和交代作用的结果[143]。

有人报道了扬子地块东部的铜金矿化与晚中生代埃达克岩有关[8,14]，并系统总结了该区铜金成矿与埃达克质岩的关系[16,85,87,90,91,95]，指出扬子地块和大别造山带的长英质埃达克岩不是由俯冲板片熔融而成，虽然同一区域与铜金矿化相关的镁铁质埃达克质岩具有显著的地幔特征。这表明：1)深部地壳熔融形成贫矿的埃达克质岩；2)拆沉下地壳熔融形成的熔体在穿过地幔后形成富矿的埃达克质岩。与下地壳拆沉作用有关的埃达克质岩的成矿潜力类似于俯冲环境。这表明埃达克岩浆对斑岩铜金矿床的形成有重要意义，而勘探的构造环境却可以扩大到板内、俯冲后的环境。

除西天山阿吾拉勒山铜矿床与二叠纪增厚下地壳熔融形成的埃达克质岩有关外[124,125]，大多数北疆地区铜金成矿与源自俯冲洋壳部分熔融形成的古生代埃达克质岩有关[7,81,88,91,94,95,104,107,119,121]。有人认为北天山铜(金)成矿与石炭纪埃达克岩-高镁安山(闪长)岩-富铌玄武岩岩石组合有关[95]；年轻

的俯冲洋壳熔融形成的埃达克质岩浆与地幔楔橄榄岩反应，由于俯冲板片产生的埃达克质岩浆具高氧逸度，与地幔楔橄榄岩的强烈相互作用导致地幔中的金属硫化物分解，成矿金属元素进入岩浆。这可能是新疆北部铜金矿化与一些埃达克岩、高镁安山(闪长)岩或富铌岛弧玄武质岩密切共生的基本原因。

5 一些地球动力学推论

(1)与埃达克岩有关的俯冲消减、底侵和陆壳生长：根据北天山石炭纪埃达克岩与同期巴音沟蛇绿岩有类似的Sr-Nd同位素组分，有人认为它们是北天山石炭纪俯冲的年轻洋壳部分熔融的产物[88,95]。因此，石炭纪时北天山是岛弧而非大陆裂谷环境，天山地区的地壳生长方式主要是侧向而不是垂向的，且俯冲洋壳的部分熔融和亏损地幔对地壳的生长有重要贡献。北准噶尔下泥盆统埃达克岩-富铌玄武岩组合表明早泥盆世古亚洲洋壳向南对哈萨克斯坦-准噶尔板块发生俯冲[114,115]。晚古生代新疆北部有两类埃达克岩：分别与俯冲洋壳板片和底侵幔源玄武质岩有关[125]。根据它们的分布和与前一类埃达克岩密切相关的高镁安山岩、富铌玄武岩、苦橄岩，认为北疆的陆壳增生方式有多样性：既有垂直的也有测向的[125]。增生过程中有洋壳板片斜俯冲、俯冲板片撕裂、板片窗、俯冲剥蚀和玄武质物质的底侵等作用；增生物质有俯冲洋壳板片、地幔楔、弧前楼柱、受地幔楔混染的洋壳板片熔体、地幔楔受板片熔体交代后形成熔体及底侵的幔源玄武质物质。有人认为，赣东北俯冲洋壳熔融而成的西湾埃达克质花岗岩的SHRIMP锆石U-Pb法年龄(968±23Ma)应重新解释为洋壳俯冲的时间，而不应该是先前所说的洋壳形成的时间[56,57]。

(2)埃达克质岩石与增厚的下地壳物质的拆沉作用：由于埃达克质岩浆源于榴辉岩相，一些研究者关注它与增厚下地壳的拆沉作用的关系[5,6,8,14,17,71]。主要表现为：1)埃达克岩浆从残余的榴辉岩质源区中抽取出来是下地壳拆沉作用的先决条件[5,6,8,14,71,86,92,149]；2)下地壳的拆沉进入下伏地幔是形成埃达克质岩浆的先决条件[11,17,18,85,87,89,91,93]。

(3)埃达克质岩与高原：实验表明，产生埃达克质岩浆的下地壳深度超过40～50 km[140,141,150,151]。基于下地壳起源埃达克质岩的成因和其他地质证据，中国东部大陆在中-晚燕山期可能是一个高原，到中-晚侏罗世开始隆升，在早白垩世减薄，高原的隆升、减薄是由陆内的造山事件和下地壳的拆沉作用的结果[5,6]。还有学者用增厚下地壳起源的埃达克岩进一步限定了晚中生代中国东部高原的大致边界[40,152]。

参考文献(References)：

[1] Defiant M J, Drummond M S. Derivation of some modern arc magmas by melting of young subducted lithosphere[J]. Nature, 1990, 347, 662－665.

[2] Wang Q, Xu J F, Wang J X, Zhao Z H, Wang R J, Qiu J X, Xiong X L, Sang L K, Peng L H. The recognization of adakite-type gneisses in the North Dabie Mountains and its implication to ultrahigh pressure metamorphic geology [J]. Chinese Science Bulletin, 2000, 45(21): 1927－1933.

[3] Wang Y, Zhang Q, Qian Q. Adakite: Geochemical characteristics and tectonic significances [J]. Sciatica Geologica Sinica, 2000, 35(2): 251－256 (in Chinese with English abstract)

[4] Xu J F, Wang Q, Yu X Y. Geochemistry of high-Mg Andesite and Adakitic andesine from the Sanchazi block of the Mian-Lue ophiolitic melange in the Qinling Mountains, central China: Evidence of partial melting of the subducted Paleo-Tethyan crust and its implication [J]. Geochemical Journal, 2000, 34: 359－377.

[5] 张旗，王焰，钱青，杨进辉，王元龙，赵太平，郭光军. 中国东部燕山期埃达克岩的特征及其构造-成矿意义[J]. 岩石学报，2001, 17: 236－244.
Zhang Qi, Wang Yan, Qian Qing, Yang Jinhui, Wang Yuanlong, Zhao Taiping, Guo Guangjun. The characteristics and tectonic-metallogenic significance of the adakites in Yanshan Period from eastern China [J]. Acta Petrologica Sinica, 2001, 17: 236－244. (in Chinese with English abstract)

[6] 张旗，钱青，王二七，王焰，赵太平，郝杰，郭光军. 燕山中晚期的中国东部高原：埃达克岩的启示[J]. 地质科学，2001, 36(2): 248－255.
Zhang Qi, Qian Qing, Wang E'qi, Wang Yan, Zhao Taiping, Hao Jie, Guo Guangjun. An east China Plateau in mid-late Yanshanian period: Iplication from adakites [J]. Chinese Journal of Geology, 2001, 36(2): 248－255. (in Chinese with English abstract).

[7] 张旗，王焰，刘红涛，王元龙，李之彤. 中国埃达克岩的时空分布及其形成背景. 附："国内关于埃达克岩的争论"[J]. 地学前缘，2003, 10(4): 385－400.
Zhang Qi, Wang Yan, Liu Hongtao, Wang Yuanlong, Li Zhitong. On the space-time distribution and geodynamic environments of adakites in China annex: for adakites in China [J]. Earth Science Frontiers, 2003, 10(4): 385－400. (in Chinese with English abstract)

[8] 王强，许继锋，赵振华. 一种新的火成岩——埃达克岩的研究综述[J]. 地球科学进展，2001, 16(2): 201－208.
Wang Qiang, Xu Jifeng, Zhao Zhenhua. The summary and comment on research on a new kind of igneous rock－Adakite [J]. Advance in Earth Science, 2001, 16(2): 201－208. (in Chinese with English abstract)

[9] Chung S L, Liu D Y, Ji J Q, Chu M F, Lee H Y, Wen D J,

Lo C H, Lee T Y, Qian Q, Zhang Q. Adakites from continental collision zones: Melting of thickened lower crust beneath southern Tibet [J]. Geology, 2003, 31 (11): 1021－1024.

[10] 翟明国. 达克岩和大陆下地壳重熔的花岗岩类[J]. 岩石学报, 2004, 20(2): 193－194.
Zhai Mingguo. Adakite and related granitoids from partial melting of continental lower crust[J]. Act Petrologica Sinica, 2004, 20(2): 193－194. (in Chinese with English abstract)

[11] Gao S, Rudnick R L, Yuan H L, Liu X M, Liu Y S, Xu W L, Lin W L, Ayers J, Wang X C, Wang Q H. Recycling lower continental crust in the North China craton[J]. Nature, 2004, 432: 892－897.

[12] 董申保, 田伟. 埃达克岩的原因、特征与成因[J]. 地学前缘, 2004, 11(4): 585－594.
Dong Shenbao, Tian Wei. The nomenclature, characteristics and petrogenesis of adakite [J]. Earth Science Frontiers, 2004, 11(4): 585－594. (in Chinese with English abstract)

[13] 牛耀龄. 玄武岩浆起源和演化的一些基本概念以及对中国东部中－新生代基性火山岩成因的新思路[J]. 高校地质学报, 2005, 11(1): 9－46.
Niu Yaoling. Generation and evolution of basaltic magmas: Some basic concepts and a new view on the origin of Mesozoic-Cenozoic basaltic volcanism in eastern China[J]. Geological Journal of China Universities, 2005, 11(1): 9－46. (in Chinese with English abstract)

[14] 王强, 赵振华, 熊小林, 许继锋. 底侵玄武质下地壳的熔融: 来自安徽沙溪 Adakite 质富钠石英闪长玢岩的证据[J]. 地球化学, 2001, 30(4): 352－362.
Wang Qiang, Zhao Zhenhua, Xiong Xiaolin, Xu Jifeng. Crustal growth and the melting of mafic lower crust: evidence from the Shaxi adakitic sodic quartz diorite-porphyrites, in Anhui Province, China[J]. Geochimica, 2001, 30(4): 352－362. (in Chinese with English abstract)

[15] Wang Q, Xu J F, Zhao Z H, Xiong X L, Bao Z W. Petrogenesis of the Mesozoic intrusive rocks in the Tongling area, Anhui Province, China and their constraint on geodynamic process[J]. Science in China(series D), 2001, 46 (8): 801－815.

[16] Wang Q, Zhao Z H, Xu J F, Li X H, Bao Z W, Xiong X L, Liu Y M. Petrogenesis and metallogenesis of the Yanshanian adakite-like rocks in the Eastern Yangtze Block[J]. Science in China(series D), 2003, 46 (suppl.): 164－176.

[17] Xu J F, Shinjo R, Defant M J, Wang Q, Rapp R P. Origin of Mesozoic adakitic intrusive rocks in the Ningzhen area of east China: Partial melting of delaminated lower continental crust? [J]. Geology, 2002, 30(12): 1111－1114.

[18] 许继峰, 王强. Adakitic 火成岩对大陆地壳增厚过程的指示: 以青藏北部火山岩为例[J]. 地学前缘, 2003, 10(4): 401－406.
Xu Jifeng, Wang Qiang. Tracing the thickening process of continental crust through studying adakitic rocks: Evidence from volcanic rocks in the North Tibet [J]. Earth Science Frontiers, 2003, 10(4): 401－406. (in Chinese with English abstract)

[19] Davis G A. 华北燕山带: 构造、埃达克质岩浆活动与地壳演化[J]. 地学前缘, 2003, (4): 373－384.
Davis G A. The Yanshan belt of north China: Tectonics, adakitic magmatism, and crustal evolution[J]. Earth Science Frontiers, 2003, 10(4): 373－384. (in Chinese with English abstract)

[20] Castillo P R. An overview of adakite petrogenesis[J]. Chinese Science Bulletin, 2006, 51(3): 257－268.

[21] 蔡志勇, 熊小林, 孙三才. 江西会昌盆地晚白垩世站塘高钠埃达克质岩石的地球化学特征及岩石成因[J]. 大地构造与成矿学, 2004, 28(4): 355－369.
Cai Zhiyong, Xiong Xiaolin, Sun Sancai. Characteristics and origin of high-Na adakite-like rocks: The Late Cretaceous Zhantann andesites in the Huichang basin, Jiangxi Province [J]. Geotectonica et Metallogenia, 2004, 28(4), 355－369. (in Chinese with English abstract)

[22] 蔡志勇, 邱瑞照, 熊小林, 黄圭成, 周肃, 孟祥金. 西藏西部地区埃达克质侵入岩及铜金找矿意义[J]. 大地构造与成矿学, 2005, 29(4): 491－501.
Cai Zhiyong, Qiu Ruizhao, Xiong Xiaolin, Huang Guicheng, Zhou Su, Meng Xiangjin. The adakite-like intrusive rocks characteristics of western Tibet and their prospecting significance[J]. Geotectonica et Metallogenia, 2005, 29(4): 491－501. (in Chinese with English abstract)

[23] Gao Y F, Hou Z Q, Wei R H, Zhao R S. Post-collisional adakitic porphyries in Tibet: Geochemical and Sr-Nd-Pb isotopic constraints on partial melting of oceanic lithosphere and crust-mantle interaction[J]. Acta Geologica Sinica, 2005, 77 (2): 194－203.

[24] 侯增谦, 莫宣学. 埃达克岩: 斑岩铜矿的一种可能的重要含矿母岩——以西藏和智利斑岩铜矿为例[J]. 矿床地质, 2003, 22(1): 1－12.
Hou Zengqian, Mo Xuanxue. Adakite: A possible host rock for porphyry copper deposits: Case studies of porphyry copper belts in Tibetan Plateau and in Northern Chile[J]. Mineral Deposits, 2003, 22(1): 1－12. (in Chinese with English abstract)

[25] 侯增谦, 孟祥金, 曲晓明, 高永丰. 西藏冈底斯斑岩铜矿带埃达克质斑岩含矿性: 源岩相变及深部过程约束[J]. 矿床地质, 2005, 24(2): 208－121.
Hou Zengqian, Meng Xiangjin, Qu Xiaoming, Gao Yongfeng. Copper ore potential of adakitic intrusives in Gangdese porphyry copper belt: Constrains from rock phase and deep melting process[J]. Mineral Deposits, 2005, 24(2): 108－121. (in Chinese with English abstract)

[26] Hou Z Q, Gao Y F, Qu X M, Rui Z Y, Mo X X. Origin of adakitic intrusives generated during mid-Miocene east-west extension in southern Tibet[J]. Earth Planet. Sci. Lett., 2004, 220: 139－155.

[27] Hou Zengqian, Gao Y F, Meng X J, Qu X M, Huang W. Genesis of adakitic porphyry and tectonic controls on the Gangdese Miocene porphyry copper belt in the Tibetan orogen[J]. Acta Petrologica Sinica, 2004, 20(2): 239－248.

(in Chinese with English abstract)

[28] 赖绍聪. 青藏高原新生代埃达克质岩的厘定及其意义[J]. 地学前缘，2003，10(4)：385－400.
Lai Shaochong. Identification of the Cenozoic adakitic rock association from Tibetan plateau and ITS[J]. Earth Science Frontiers, 2003, 10(4): 385－400. (in Chinese with English abstract)

[29] 魏君奇，姚华舟，牛志军，王建雄. 藏北赤布张错地区埃达克岩的厘定及其意义[J]. 岩石矿物学杂志，2005，24(3)：173－178.
Wei Junqi, Yao Huazhou, Niu Zhijun, Wang Jianxiong. Identification of the adakitic rock association in Chibzhang Co area, northern Tibet, and its significance[J]. Acta Petrologica et Mineralogica, 2005, 24(3): 173－178. (in Chinese with English abstract)

[30] 武广，李忠权，李之彤. 辽西地区早中生代火山岩地球化学特征及成因探讨[J]. 矿物岩石，2003，23(3)：44－50.
Wu Guang., Li Zhongquan, Li Zhitong. Geochemical characteristics and genesis of the early Mesozoic volcanic rocks in west Liaoning area[J]. Journal of Mineralogica and Petrologica, 2003, 23(3): 44－50. (in Chinese with English abstract)

[31] 武广，李忠权，李之彤. 辽西中侏罗统海房沟组埃达克质岩的确认及地质意义[J]. 成都理工大学学报(自然科学版)，2003，30(5)：457－461.
Wu Guang, Li Zhongquan, Li Zhitong. Identification of adakite-like rocks in the middle Jurassic volcanic rocks from Haifang formation in west Liaoning area and its geological significance[J]. Journal of Chengdu University of Technology, 2003, 30(5): 457－461. (in Chinese with English abstract)

[32] 肖龙，Rapp P R，许继峰. 深部过程对埃达克质岩石成分的制约[J]. 岩石学报，2004，20(2)：219－228.
Xiao Long, Rapp P R, Xu Jifeng. The role of deep processes controls on variation of compositions of adakitic rocks[J]. Acta Petrologica Sinica, 2004, 20(2): 219－228. (in Chinese with English abstract)

[33] 许立权，邓晋福，陈志勇，陶继雄. 内蒙古达茂旗北部奥陶纪埃达克岩类的识别及其意义[J]. 现代地质，2003，17(4)：428－434.
Xu Liquan, Deng Jinfu, Chen Zhiyong, Tao Jixiong. The identification of ordovician adakites and its signification in northern damao inner Mongolia[J]. Geoscience, 2003, 17(4): 428－434. (in Chinese with English abstract)

[34] 赵振华，熊小林，王强，白正华，梅厚钧. 新疆西天山莫斯早特石英钠长斑岩铜矿床一个与埃达克质岩石有关的铜矿实例[J]. 岩石学报，2004，20(2)：249－258.
Zhao Zhenhua, Xiong Xiaolin, Wang Qiang, Bai Zhenghua, Mei Houjun. A case study on porphyry copper deposit related with adakitic quartz albite porphyry in Mosizaote, Western Tianshan, Xinjiang, China[J]. Acta Petrologica Sinica, 2004, 20(2): 249－258. (in Chinese with English abstract)

[35] Zhao Z H, Xiong X L, Wang Q, Bai Z H, Xu J F, Qiao Y L. Association of Late Paleozoic Adakitic Rocks and Shoshonitic Volcanic Rocks in the Western Tianshan, China[J]. Acta Geologica Sinica, 2004, 78(1): 68－72.

[36] Xu W L, Wang Q H, Wang D Y, Guo J H, Pei F P. Mesozoic adakitic rocks from the Xuzhou－Suzhou area, eastern China: Evidence for partial melting of delaminated lower continental crust[J]. Journal of Asian Earth Sciences, 2006, 27(4): 454－46.

[37] 王金荣，郭原生，付善明，陈建林，秦秀峰，张洪培，杨永均. 甘肃黑石山早古生代埃达克质岩的发现及其构造动力学意义[J]. 岩石学报，2005，21(3)：977－985.
Wang Jinrong, Guo Yuansheng, Fu Shanming, Chen Jianlin, Qin Xiufeng, Zhang Hongpei, Yang Yongjun. Early Paleozoic adakitic rocks in Heishishan, Gansu and their significance for tectonodynamics[J]. Acta Petrologica Sinica, 2005, 21(3): 977－985. (in Chinese with English abstract)

[38] 苏建平，张新虎，胡能高，付国民，张海峰. 中祁连西段野马南山埃达克质花岗岩的地球化学特征及成因[J]. 中国地质，2004，31(4)：365－371.
Su Jianping, Zhang Xinhu, Hu Nenggao, Fu Guomin, Zhang Haifeng. Geochemical characteristics and genesis of adakite－like granites at Yema Nanshan in the western segment of the Central Qilian Mountains[J]. Geology in China, 2005, 31(4): 365－371. (in Chinese with English abstract)

[39] 张旗，许继峰，王焰，肖龙，刘红涛，王元龙. 埃达克岩的多样性[J]. 地质通报，2004，23(9－10)：959－965.
Zhang Qi, Xu Jifeng, Wang Yan, Xiao Long, Liu Hongtao, Wang Yuanlong. Diversity of adakite[J]. Geological Bulletin in China, 2004, 23(9－10): 959－965. (in Chinese with English abstract)

[40] 张旗，李承东，王焰，王云龙，金惟俊，贾秀勤，韩松. 中国东部中生代高 Sr 低 Yb 和低 Sr 高 Yb 型花岗岩：对比及其地质意义[J]. 岩石学报，2005，21(6)：1527－1537.
Zhang Qi, Li Chengdong, Wang Yan, Wang Yunlong, Jin Weijun, Jia Xiuqin, Han Song. Mesozoic high-Sr and low－Yb granitoids and low-Sr and high-Yb granitoids in eastern China: Comparison and geological implications[J]. Acta Petrologica Sinica, 2004, 21(6): 1527－1537. (in Chinese with English abstract)

[41] 李承东，张旗，苗来成，孟宪锋. 冀北中生代高 Sr 低 Y 和低 Sr 低 Y 型花岗岩：地球化学、成因及其与成矿作用的关系[J]. 岩石学报，2004，20(2)：269－284.
Li Chengdong, Zhang Qi, Miao Laicheng, Meng Xianfeng. Mesozoic high-Sr, low-Y and low-Sr, low-Y types Granitoids in the northern Hebei Province: Geochemistry and Petrogenesis and its relation to mineralization of gold deposits[J]. Acta Petrologica Sinica, 2004, 20: 269－284. (in Chinese with English abstract)

[42] 蔡剑辉，阎国翰，常兆山，王晓芳，邵宏翔，储著银. 王安镇岩体岩石地球化学特征及成因探讨[J]. 岩石学报，2003，19(1)：81－92.
Cai Jianhui, Yan Guohan, Chang Zhaoshan, Wang Xiaofang, Shao Hongxiang, Chu Zhuyin. Petrological and geochemical characteristics of the Wanganzhen complex and discussion on its genesis[J]. Acta Petrologica Sinica, 2003, 19(1): 81－

92. (in Chinese with English abstract)

[43] 蔡剑辉，阎国翰，牟保磊，任康绪，宋彪，李凤棠. 北京房山岩体锆石 U-Pb 年龄和 Sr、Nd、Pb 同位素与微量元素特征及成因探讨[J]. 岩石学报，2005，21(3)：776－788.
Cai Jianhui, Yan Guohan, Mu Baolei, Reng Kangxu, Song Biao, Li Fengtang. Zircon U-Pb age, Sr-Nd-Pb isotopic compositions and trace element of Fangshan complex in Beijing and their petrogenesis significance[J]. Acta Petrologica Sinica, 2005, 21(3): 776－788. (in Chinese with English abstract)

[44] 陈军强，孙景贵，朴寿成，赵俊康，翟玉峰. 金厂沟梁金矿区暗色脉岩的成因和意义：主要和微量元素地球化学证据[J]. 吉林大学学报(地球科学版)，2005，35(6)：707－713.
Chen Junqiang, Sun Jinggui, Piao Shoucheng, Zhao Junkang, Zhai Yufeng. Genesis and significance of Dark Dikes in the Jinchanggouliang mine area, Inner Mongolia: Evidences from geochemistry of the major and trace elements[J]. Journal of Jilin University (Earth Science Edition), 2005, 35 (6): 707－713. (in Chinese with English abstract)

[45] 付善明，周永章，郭原生，杨志军，付伟. 甘肃黑石山埃达克岩金矿床成矿模式初析[J]. 矿床地质，2005，24(6)：669－675.
Fu Shanming, Zhou Yongzhang, Guo Yuansheng, Yang Zhijun, Fu Wei. Metallogenic model of Heishishan adakite gold deposit in Gansu Province[J]. Mineral Deposits, 2005, 24 (6): 669－675. (in Chinese with English abstract)

[46] 高晓峰，郭锋，范蔚茗，李超文，李晓勇. 南兴安岭晚中生代中酸性火山岩的岩石成因[J]. 岩石学报，2005，21(3)：737－748.
Gao Xiaofeng, Guo Feng, Fan Weiming, Li Chaowen, Li Xiaoyong. Origin of late Mesozoic intermediate-felsic volcanic rocks from the northern Da Hinggan Mountain, NE China [J]. Acta Petrologica Sinica, 2005, 21(3): 737－748. (in Chinese with English abstract)

[47] Gao Y F, Hou Z Q, Kamber B S, Wei R H, Meng X J, Zhao R S. Adakite-like porphyries from the southern Tibetan continental collision zones: Evidence for slab melt metasomatism [J]. Contribution to Mineralogy and Petrology, 2007, 153: 105－120.

[48] 高永丰，侯增谦，魏瑞华. 冈底斯晚第三纪斑岩的岩石学、地球化学及其地球动力学意义[J]. 岩石学报，2003，19(3)：418－428.
Gao Yongfeng, Hou Zengqian, Wei Ruihua. Neogene porphyries from Gangdese: petrological, geochemical characteristics and Geodynamic significances[J]. Acta Petrologica Sinica, 2003, 19(3): 418－428. (in Chinese with English abstract)

[49] Guo F, Fan W M, Li C W. Geochemistry of late Mesozoic adakites from the Sulu belt, eastern China: Magma genesis and implications for crustal recycling beneath continental collisional orogens[J]. Geological Magazine, 2006, 143(1): 1－13.

[50] Han C M, Xiao W J, Zhao G C, Mao J W, Yang J M, Wang Z L, Yan Z, Mao Q G. Geological characteristics and genesis of the Tuwu porphyry copper deposit, Hami, Xinjiang, Central Asia[J]. Ore Geology Reviews, 2006, 29: 77－94.

[51] 黄增保，魏志军，金霞. 甘肃北山460金矿埃达克质石英闪长岩地球化学特征及意义[J]. 甘肃地质学报，2005，14(2)：30－34.
Huang Zengbao, Wei Zhijun, Jin Xia. The geochemical characteristics of mine adakitic quartz-diorite complex from the Beishan area, Gansu Province and its geological significance [J]. Acta Geologica Gansu, 2005, 14(2): 30－34. (in Chinese with English abstract)

[52] 简平，刘敦一，张旗，张福勤，石玉若，施光海，张履桥，陶华. 蛇绿岩及蛇绿岩中浅色岩的 SHRIMP U-Pb 测年[J]. 地学前缘，2003，10(4)：439－456.
Jian Ping, Liu Dunyi, Zhang Qi, Zhang Fuqin, Shi Yuruo, Shi Guanghai, Zhang Lüqiao, Tao Hua. SHRIMP dating of ophiolite and leucocratic rocks within ophiolite[J]. Earth Science Frontiers, 2003, 10(4): 439－456. (in Chinese with English abstract)

[53] 金维浚，张旗，何登发，贾秀勤. 西秦岭埃达克岩的 SHRIMP 定年及其构造意义[J]. 岩石学报，2005，21(3)：959－966.
Jin Weijun, Zhang Qi, He Dengfa, Jia Xiuqin. SHRIMP dating of adakites in western Qinling and their implications[J]. Acta Petrologica Sinica, 2005, 21(3): 959－966. (in Chinese with English abstract).

[54] 柯珊，莫宣学，罗照华，詹华明，梁涛，李莉，李文韬. 塔什库尔干新生代碱性杂岩的地球化学特征及岩石成因[J]. 岩石学报，2006，22(4)：905－915.
Ke Shan, Mo Xuanxue, Luo Zhaohua, Zhan Huaming, Liang Tao, Li Li, Li Wentao. Petrogenesis and geochemistry of Cenozoic Taxkorgan alkalic complex and its geological significance[J]. Acta Petrologica Sinica, 2006, 22 (4): 905－915. (in Chinese with English abstract)

[55] Lai S C, Liu C Y, Yi H S. Geochemistry and petrogenesis of Cenozoic andesite-dacite associations from the Hoh Xil Region, Tibetan Plateau[J]. International Geology Review, 2003, 45(11): 998－1019.

[56] Li W X, Li X H. Adakitic granites within the NE Jiangxi ophiolites, South China: geochemical and Nd isotopic evidence[J]. Precam. Res., 2003, 122 (1－4): 29－44.

[57] 李显武，李献华. 赣东北蛇绿岩中的埃达克型花岗岩——地球化学和 Nd 同位素证据[J]. 高校地质学报，2004，10(2)：199－208.
Li Xianwu, Li Xianhua. Adakitic granites within the NE Jiangxi ophiolites, South China－Geochemical and Nd isotopic evidence[J]. Gelogical Journal of China Universities, 2004, 10(2), 199－208. (in Chinese with English abstract)

[58] 刘德权，陈毓川，王登红，唐延龄，周汝洪，王金良，李华芹，陈富文. 土屋-延东铜钼矿田与成矿有关问题的讨论[J]. 矿床地质，2003，22(4)：334－344.
Liu Dequan, Chen Yuchuan, Wang Denghong, Tang Yanling, Zhou Ruhong, Wang Jinliang, Li Huaqin, Chen Fuwen. A discussion on problems related to mineralization of

Tuwu-Yandong Cu-Mo ore field in Hami, Xinjiang[J]. Mineral Deposites, 2003, 22(4): 334－344. (in Chinese with English abstract)

[59] 刘敦一，简平，张旗，张福勤，石玉若，施光海，张履桥，陶华. 内蒙古图林凯蛇绿岩中埃达克岩 SHRIMP 测年：早古生代洋壳消减的证据[J]. 地质学报，2003，77(3)：317－327.
Liu Dunyi, Jian Ping, Zhang Qi, Zhang Fuqin, Shi Yuruo, Shi Guanghai, Zhang lüqiao, Tao Hua. SHRIMP dating of adakites in the Tulingkai ophiolite, Inner Mongolia: Evidence for the Early Paleozoic subduction[J]. Acta Geologica Sinica, 2003, 77(3): 317－327. (in Chinese with English abstract)

[60] Liu S, Hu R Z, Feng C X, Chi X G, Li C, Yang R H, Wang T W, Jin W. Cenozoic adakite-type volcanic rocks in Qiangtang, Tibet and its significance[J]. Acta Geologica Sinica, 2003, 77 (2): 187－193.

[61] 刘文斌，刘振宏，张世佼. 河南商城岩体地质地球化学特征及成因意义[J]. 华南地质与矿产，2003，03(4)：17－23.
Liu Wenbin, Liu Zhenhong, Zhang Shijiao. Geological and geochemical features of Shangcheng granite body and its genetic implication, Henan[J]. Geology and Mineral Resources of South China, 2003, (4): 17－23. (in Chinese with English abstract)

[62] 罗小洪. 九瑞地区中生代岩浆活动及其大地构造意义[J]. 东华理工学院学报，2006 29(2)：121－126.
Luo Xiaohong. Geochemistry of ore-bearing porphyries in the Kalaxianger copper belt on the southeastern margin of the Altay Mountains, Xinjiang[J]. Journal of East China Institute of Technology, 2006, 29(2): 121－126. (in Chinese with English abstract)

[63] Ma C Q, Yang K G., Ming H L. The timing of tectonic transition from compression to extension in Dabieshan: Evidence from Mesozoic granites[J]. Science in China (series D), 2004, 47: 453－462.

[64] 毛德宝，钟长汀，赵风清，陈志宏，左义成，胡小蝶. 冀北郭家屯地区中生代火山岩年代学和地球化学特征研究[J]. 地球化学，2005，34(6)：574－586.
Mao Debao, Zhong Changting, Zhao Fengqing, Chen Zhihong, Zuo Yicheng, Hu Xiaodie. Geochronology and geochemistry of the Mesozoic volcanic-subvolcanic rocks in west Longhua area, northern Hebei Province[J]. Geochimica, 2005, 34(6): 574－586. (in Chinese with English abstract)

[65] Mao J R, Hu Q, Xu N Z, Chen R, Ye U M, Zhao X L. Mesozoic magmatism and copper polymetallic mineralization processes in the Shanghang-Datian region, Fujian Province, Southeast China[J]. Chinese Journal of Geochemistry, 2006, 25(3): 266－278.

[66] 毛建仁，许乃政，胡青，李寄嵎，谢芳贵. 闽西南地区中生代花岗闪长质岩石的同位素年代学、地球化学及其构造演化[J]. 吉林大学学报(地球科学版)，2004，34(1)：12－20.
Mao Jianren, Xu Naizheng, Hu Qing, Li Jiyu, Xie Fanggui. Geochronology and geochemical characteristics in Mesozoic granodioritic rocks in southwestern Fujian, and their tectonic evolution[J]. Journal of Jilin University (Earth Science Edition), 2004, 34(1): 12－20. (in Chinese with English abstract)

[67] 毛建仁，许乃政，胡青，刑光福，杨祝良. 福建省上杭－大田地区中生代成岩成矿作用与构造环境演化[J]. 岩石学报，2004，20(2)：285－296.
Mao Jianren, Xu Naizheng, Hu Qing, Xing Guangfu, Yang Zhuliang. The Mesozoic rock-forming and ore-forming processes and tectonic environment evolution in Shanghang-Datian region, Fujian[J]. Acta Petrologica Sinica, 2004, 20 (2): 285－296. (in Chinese with English abstract)

[68] 莫宣学，赵志丹，DePaolo D J，周肃，董国臣. 青藏高原拉萨地块碰撞-后碰撞岩浆作用的三种类型及其对大陆俯冲和成矿作用的启示：Sr-Nd 同位素证据[J]. 岩石学报，2006，22 (4)：795－803.
Mo Xuanxue, Zhao Zhidan, DePaolo D J, Zhou Su, Dong Guochen. Three types of collisional and post-collisional magmatism in the Lhasa block, Tibet and implications for India intra-continental subduction and mineralization: evidence from Sr-Nd isotopes[J]. Acta Petrologica Sinica, 2006, 22 (4): 795－803. (in Chinese with English abstract)

[69] Niu H, Sato H, Zhang H, Ito J I, Yu X, Nagao T, Terada K, Zhang Q. Juxtaposition of adakite, boninite, high-TiO_2 and low-TiO_2 basalts in the Devonian southern Altay, Xinjiang, NW China[J]. Journal of Asian Earth Sciences, 2006, 28: 439－456.

[70] 裴先治，王涛，丁仨平，李勇，胡波. 东秦岭商丹带北侧新元古代埃达克质花岗岩及其地质意义[J]. 中国地质，2003，30 (4)：372－381.
Pei Xianzhi, Wang Tao, Ding Saping, Li Yong, Hu Bo. Geochemical characteristics and geological significance of Neoproterozoic adakitic granitoids on the north side of the Shangdan zone in the East Qinling[J]. Geology in China, 2003, 30 (4): 372－381. (in Chinese with English abstract)

[71] 钱青. Adakite 的地球化学特征及成因[J]. 矿物岩石学杂志，2001，20(3)：297－306.
Qian Qing. Adakite: Geochemicai characteristics and genesis [J]. Acta Petrologica et Mineralogica, 2001, 20 (3): 297－306. (in Chinese with English abstract)

[72] 秦江锋，赖绍聪，李永飞. 扬子板块北缘碧口地区阳坝花岗闪长岩体成因研究及其地质意义[J]. 岩石学报，2005，21(3)：697－710.
Qin Jiangfeng, Lai Shaochong, Li Yongfei. Petrogenesis and geological significance of Yangba granodiorites from Bikou area, northern margin of Yangtze Plate[J]. Acta Petrologica Sinica, 2005, 21(3): 697－710. (in Chinese with English abstract)

[73] 秦社彩，范蔚茗，郭锋，李超文，高晓峰. 浙江浦江晚中生代埃达克质火山岩的成因[J]. 岩石学报，2006，22(9)：2305－2314.
Qin Shecai, Fan Weiming, Guo Feng, Li Chaowen, Gao Xiaofeng. Petrogenesis of late Mesozoic adakitic andesites from Pujiang area in Zhejiang Province, eastern China[J]. Acta Petrologica Sinica, 2006, 22(9): 2305－2314. (in Chinese

with English abstract)

[74] Qu X M, Hou Z Q, Li Y G. Melt components derived from a subducted slab in late orogenic ore-bearing porphyries in the Gangdese copper belt, southern Tibetan plateau[J]. Lithos, 2004, 74: 131－148.

[75] 曲晓明，侯增谦，李振清. 冈底斯铜矿带含矿斑岩的$^{40}Ar/^{39}Ar$年龄及地质意义[J]. 地质学报，2003，77(2)：245－252.
Qu Xiaoming, Hou Zengqian, Li Zhenqing. $^{40}Ar/^{39}Ar$ Ages of the ore-bearing orphyries of the Gangdese porphyry copper belt and their geological significances[J]. Acta Geologica Sinica, 2003, 77(2): 245－252. (in Chinese with English abstract)

[76] 曲晓明，侯增谦，国连杰，徐文艺. 冈底斯铜矿带埃达克含矿斑岩的源区组成与地壳混染：Nd、Sr、Pb、O 同位素约束[J]. 地质学报，2004，78(6)：813－821.
Qu Xiaoming, Hou Zengqian, Guo Lianjie, Xu Wenyi. Source compositions and crustal contaminations of adakitic ore-bearing porphyries in the Gangdise copper belt: Nd, Sr, Pb and O isotope constraints[J]. Acta Geologica Sinica, 2004, 78(6): 813－821. (in Chinese with English abstract)

[77] 史仁灯，杨经绥，吴才来. 柴北缘早古生代岛弧火山岩中埃达克质英安岩的发现及其地质意义[J]. 岩石矿物学杂志，2003，22(3)：229－236.
Shi Rendeng, Yang Jingsui, Wu Cailai. The discovery of adakitic dacite in Early Palaeozoic island arc volcanic rocks on the northern margin of Qaidam basin and its geological significance[J]. Acta Petrologica et Mineralogica, 2003, 22(3): 229－236. (in Chinese with English abstract)

[78] 石玉若，刘敦一，张旗，简平，张福勤，苗来成，施光海，张履桥，陶华. 内蒙古苏左旗白音宝力道 Adakite 质岩类成因探讨及其 SHRIMP 年代学研究[J]. 岩石学报，2005，21(1)：143－150.
Shi Yuruo, Liu Dunyi, Zhang Qi, Jian Ping, Zhang Fuqin, Miao Laicheng, Shi Guanghai, Zhang Lüqiao, Tao Hua. The petrogenesis and SHRIMP dating of the Baiyinbaolidao adakitic rocks in southern Suzuoqi, Inner Mongolia[J]. Acta Petrologica Sinica, 2005, 21(1): 143－150. (in Chinese with English abstract)

[79] 陶继东，张超，马昌前，杨坤光，周红升. 房山侵入岩体高 Sr 低 Y 地球化学特征及其成因[J]. 地质科技情报，2006，25(2)：11－18.
Tao Jidong, Zhang Chao, Ma Changqian, Yang Kunguang, Zhou Hongsheng. Chemistry and petrogenesis of cretaceous high Sr and low Y granodiorite pluton in Fangshan area, Beijing[J]. Geological Science and Technology Information, 2006, 25(2): 11－18. (in Chinese with English abstract)

[80] 陶继雄，许立权，贺锋，苏茂荣. 内蒙古巴特敖包地区早古生代洋壳消减的岩石证据[J]. 地质调查与研究，2005，28(1)：1－8.
Tao Jixiong, Xu Liquan, He Feng, Su Maorong. Petrological evidence for subduction of the Early Paleozoic oceanic crust in Bart-Obo, Inner Mongolia[J]. Geological Survey and Research, 2005, 28(1): 1－8. (in Chinese with English abstract)

[81] 万博，张连昌. 新疆阿尔泰东南缘卡拉先格尔铜矿带含矿斑岩地球化学及其成矿意义[J]. 中国地质，2006，33(3)：618－625.
Wan Bo, Zhang Lianchang. Geochemistry of ore-bearing porphyries in the Kalaxianger copper belt on the southeastern margin of the Altay Mountains, Xinjiang[J]. Geology in China, 2006, 33(3): 618－625. (in Chinese with English abstract)

[82] 王金荣，吴春俊，蔡郑红，郭原生，吴继承，刘晓煌. 北祁连山东段银硐梁早古生代高镁埃达克岩：地球动力学及成矿意义[J]. 岩石学报，2006，22(11)：2655－2664.
Wang Jinrong, Wu Chunjun, Cai Zhenghong, Guo Yuansheng, Wu Jicheng, Liu Xiaohuang. Early Paleozoic high-Mg adakite from Yindongliang in the eastern section of the north Qilian: Implications for geodynamics and Cu-Au mineraliztion[J]. Acta Petrologica Sinica, 2006, 22(11): 2655－2664. (in Chinese with English abstract)

[83] 王清海，许文良，王冬艳，林景仟. 徐州－宿州地区中生代埃达克质岩石岩浆起源深度的限定——深源捕掳体温度-压力条件证据[J]. 地质评论，2004，50(4)：351－359.
Wang Qinghai, Xu Wenliang, Wang Dongyan, Lin Jingqian. Determination of the magma depth of the Mesozoic adakitic rocks in the Xuzhou-Suzhou area: Evidence from p-T estimation of deep-seated xenoliths[J]. Geological Review, 2004, 50(4): 351－359. (in Chinese with English abstract)

[84] Wang Q, McDermott F, Xu J F, Bellon H, Zhu Y T. Cenozoic K-rich adakitic volcanic rocks in the Hohxil area, northern Tibet: Lower-crustal melting in an intracontinental setting[J]. Geology, 2005, 33: 465－468.

[85] Wang Q, Wyman D A, Xu J F, Zhao Z H, Jian P, Xiong X L, Bao Z W, Li C F, Bai Z H. Petrogenesis of Cretaceous adakitic and shoshonitic igneous rocks in the Luzong area, Anhui Province (eastern China): Implications for geodynamics and Cu-Au mineralization[J]. Lithos, 2006, 89: 424－446.

[86] Wang Q, Wyman A, Xu J F, Jian P, Zhao Z H, Li C F, Xu W, Ma J L, He B. Early Cretaceous adakitic granites in the northern Dabie complex, central China: Implications for partial melting and delamination of thickened lower crust[J]. Geochim. Cosmochim. Acta, 2007 (in press).

[87] Wang Q, Wyman D A, Xu J F, Zhao Z H, Jian P, Zi F. Partial melting of thickened or delaminated lower crust in the middle of eastern China: Implications for Cu-Au mineralization[J]. The Journal of Geology, 2007, 115: 149－161.

[88] Wang Q, Wyman D A, Zhao Z H, Xu J F, Bai Z H, Xiong X L, Dai T M, Li C F, Chu Z Y. Petrogenesis of Carboniferous adakites and Nb-enriched arc basalts in the Alataw area, northern Tianshan Range (western China): Implication for Phanerozoic crustal growth of Central Asia Orogenic Belt[J]. Chemical Geology, 2007, 236: 42－64.

[89] Wang Q, Xu J F, Zhao Z H, Bao Z W, Xiong X L. Cretaceous high-potassium intrusive rocks in the Yueshan-Hongzhen area of

east China: Adakites in an extensional tectonic regime within a continent[J]. Geochem. J., 2004, 38: 417-434.

[90] Wang Q, Xu J F, Jian P, Bao Z W, Zhao Z H, Li C F, Xiong X L, Ma J L. Petrogenesis of adakitic porphyries in an extensional tectonic setting, Dexing, South China: Implications for the genesis of porphyry copper mineralization[J]. J. Petrol., 2006, 47(1): 119-144.

[91] 王强，许继峰，赵振华. 强烈亏损重稀土元素的中酸性火成岩(或埃达克质岩)与Cu、Au成矿作用[J]. 地学前缘，2003，10(4): 561-572.
Wang Qiang, Xu Jifeng, Zhao Zhenhua. Intermediate-acid igneous rocks strongly depleted in heavy rare earth element (or adakitic rocks) and copper-gold metallogenesis[J]. Earth Science Frontiers, 2003, 10(4): 561-572. (in Chinese with English abstract)

[92] 王强，许继锋，赵振华，王人镜，邱家骧，包志伟. 大别山燕山期亏损重稀土元素花岗岩类的成因及动力学意义[J]. 岩石学报，2001，17(4): 551-564.
Wang Qiang, Xu Jifeng, Zhao Zhenhua, Wang Renjing, Qiu Jiaxiang, Bao Zhiwei. The petrogenesis and geodynamic significances of heavy rare earth element (HREE)-depleted granitoids during Yanshanian period in the Dabie Mountains [J]. Acta Petrologica Sinica, 2001, 17(4): 551-564. (in Chinese with English abstract)

[93] Wang Q, Zhao Z H, Bao Z W, Xu J F, Liu W, Li C F, Bai Z H, Xiong X L. Geochemistry and petrogenesis of the Tongshankou and Yinzu adakitic intrusive rocks and the associated porphyry copper-molybdenum mineralization in southeast Hubei, east China[J]. Resource Geology, 2004, 54(2): 137-152.

[94] Wang Q, Zhao Z H, Bai, Z H, Bao, Z W, Xiong X L, Mei H J, Xu J F, Wang Y X. Carboniferous adakites and Nb-enriched arc basaltic rocks association in the Alataw Mountains, north Xinjiang: interactions between slab melt and mantle peridotite and implications for crustal growth[J]. Chinese Science Bulletin, 2003, 48 (19): 2108-2115.

[95] 王强，赵振华，许继峰，Wyman D A，熊小林，资峰，白正华. 天山北部石炭纪埃达克岩-高镁安山岩-富Nb岛弧玄武质岩：对中亚造山带显生宙地壳增生与铜金成矿的意义[J]. 岩石学报，2006，22(1): 11-30.
Wang Qiang, Zhao Zhenhua, Xu Jifeng, Wyman D A, Xiong Xiaolin, Zi Feng, Bai Zhenghua. Carboniferous adakite-high-Mg andesite-Nb-enriched basaltic rock suites in the Northern Tianshan area: Implications for Phanerozoic crustal growth in the Central Asia Orogenic Belt and Cu-Au mineralization[J]. Acta Petrologica Sinica, 2006, 22(1): 11-30. (in Chinese with English abstract)

[96] Wang X C, Liu Y S, Liu X M. Mesozoic adakites in the Lingiu Basin of the Central North China Craton: Partial melting of underplated basaltic lower crust[J]. Geochem. J., 2006, 40: 447-461.

[97] Wang X R, Gao S, Liu X M, Yuan H L, Hu Z C, Zhang H, Wang X C. Geochemistry of high-Mg andesites from the early Cretaceous Yixian Formation, western Liaoning: Implications for lower crustal delamination and Sr/Y variations[J]. Science in China(series D), 2006, 49: 904-914.

[98] 王元龙，张旗，成守德，王焰. 新藏公路128公里岩体地球化学特征及其地质意义[J]. 新疆地质，2003，21(4): 387-392.
Wang Yuanlong, Zhang Qi, Cheng Shoude, Wang Yan. Geochemical characteristics and implications of intrusion at the 128km sign of Xinjiang-Tibet highway [J]. Xinjiang Geology, 2003, 21(4): 387-392. (in Chinese with English abstract)

[99] 汪洋，邓晋福，姬广义. 长江中下游地区早白垩世埃达克质岩的大地构造背景及其成矿意义[J]. 岩石学报，2004，20(2): 297-314.
Wang Yang, Deng Jinfu, Ji Guangyi. A perspective on the geotectonic setting of early Cretaceous adakite-like rocks in the Lower Reaches of Yangtze River and its significance for copper-gold mineralization [J]. Acta Petrologica Sinica, 2004, 20(2): 297-314. (in Chinese with English abstract)

[100] 王元龙，王焰，张旗，贾秀琴，韩松. 铜陵地区中生代中酸性侵入岩的地球化学特征及其成矿——地球动力学意义[J]. 岩石学报，2004，20(2): 325-338.
Wang Yuanlong, Wang Yan, Zhang Qi, Jia Xiuqin, Han Song. The geochemical characteristics of Mesozoic intermediate-acid intrusives of the Tongling area and its metallogenesis-geodynamic implications, Anhui Province[J]. Acta Petrologica Sinica, 2004, 20: 325-338. (in Chinese with English abstract)

[101] Wang Z H, Wilde S A, Wang K Y, Yu L J. A MORB-arc basalt-adakite association in the 2.5 Ga Wutai greenstone belt: late Archean magmatism and crustal growth in the North China Craton[J]. Precam. Res., 2004, 131 (3-4): 323-343.

[102] 武占祖，陈勇，梁旭辉. 埃达克岩的研究现状及其趋势[J]. 地质找矿论丛，2005，20(3): 204-208.
Wu Zhanzu, Chen Yong, Liang Xuhui. The current situation and tendency of research on adakite[J]. Contributions to Geology and Mineral Resources Research, 2004, 20(3): 204-208. (in Chinese with English abstract)

[103] 肖文交，韩春明，袁超，陈汉林，孙敏，林寿发，厉子龙，毛启贵，张继恩，孙枢，李继亮. 新疆北部石炭纪—二叠纪独特的构造-成矿作用：对古亚洲洋构造域南部大地构造演化的制约[J]. 岩石学报，2006，22(5): 1062-1076.
Xiao Wenjiao, Han Chunming, Yuan Chao, Chen Hanlin, Sun Min, Lin Shoufa, Li Zilong, Mao Qigui, Zhang Ji'en, Sun Shu, Li Jiliang. Unique Carboniferous-Permian tectonic-metallogenic framework of Northern Xinjiang (NW China): Constraints for the tectonics of the southern Paleoasian Domain[J]. Acta Petrologica Sinica, 2006, 22 (5): 1062-1076. (in Chinese with English abstract)

[104] 熊小林，蔡志勇，牛贺才，陈义兵，王强，赵振华，吴金花. 东天山晚古生代埃达克岩成因及铜金成矿意义[J]. 岩石学报，2005，21(3): 967-976.

Xiong Xiaolin, Cai Zhiyong, Niu Hecai, Chen Yibing, Wang Qiang, Zhao Zhenhua, Wu Jinhua. The late Paleozoic adakites in eastern Tianshan area and their metallogenetic significance[J]. Acta Petrologica Sinica, 2005, 21(3): 967—976. (in Chinese with English abstract)

[105] Xiong X L, Li X H, Xu J F, Li W X, Zhao Z H, Wang Q, Chen X M. Extremely high-Na adakite-like magmas derived from alkali-rich basaltic underplate: The Late Cretaceous Zhantang andesites in the Huichang Basin, SE China[J]. Geochemical Journal, 2003, 37 (2): 233—252.

[106] Xue H M, Dong S W, Jian P. Mineral chemistry, geochemistry and U-Pb SHRIMP zircon data of the Yangxin monzonitic intrusive in the foreland of the Dabie orogen[J]. Science in China (series D), 2006, 36(2): 133—142.

[107] 杨文平，张招崇，周刚，闫升好，何立新，陈柏林. 阿尔泰铜矿带南缘希勒克特哈腊苏斑岩铜矿的发现及其意义[J]. 中国地质，2005，32(1)：107—114.

Yang Wenping, Zhang Zhaochong, Zhou Gang, Yan Shenghao, He Lixin, Chen Bolin. Discovery of the Xileketehalsu porphyry copper deposit on the southern margin of the Altay copper metallogenic belt[J]. Geology in China, 2005, 32 (1): 107—114. (in Chinese with English abstract)

[108] 姚鹏，李金高，王全海，顾雪祥，唐菊兴，惠兰. 西藏冈底斯南缘火山-岩浆弧带中桑日群 adakite 的发现及其意义[J]. 岩石学报，2006，22(3)：612—620.

Yao Peng, Li Jingao, Wang Quanhai, Gu Xuexiang, Tang Jüxing, Hui Lan. Discovery and geological significance of the adakite in Gangdise island arc belt, Xizang (Tibet) [J]. Acta Petrologica Sinica, 2006, 22 (3): 612—620. (in Chinese with English abstract)

[109] 袁超，孙敏，肖文交，周辉，侯泉林，李继亮. 原特提斯的消减极性：西昆仑 128 公里岩体的启示[J]. 岩石学报，2003，19(3)：399—408.

Yuan Chao, Sun Min, Xiao Wenjiao, Zhou Hui, Hou Quanlin, Li Jiliang. Subduction polarity of the prototethys: Insights from the Yirba pluton of the western Kunlun range, NW China[J]. Acta Petrologica Sinica, 2003, 19 (3): 399—408. (in Chinese with English abstract)

[110] Yuan H L, Liu, X M, Liu, Y S, Gao, S Ling, W L. Geochemistry and U-Pb zircon geochronology of Late-Mesozoic lavas from Xishan, Beijing[J]. Science in China (series D), 2006, 35(1): 50—67.

[111] 曾普胜，李文昌，王海平，李红. 云南普朗印支期超大型斑岩铜矿床：岩石学及年代学特征[J]. 岩石学报，2006，22(4)：989—1000.

Zeng Pusheng, Li Wenchang, Wang Haiping, Li Hong. The Indosinian Pulang superlarge porphyry copper deposit in Yunnan, China: Petrology and chronology[J]. Acta Petrologica Sinica, 2006, 22(4): 989—1000. (in Chinese with English abstract)

[112] Zhang H F, Zhang B R, Harris N, Zhang L, Chen Y L, Chen N S, Zhao Z D. U-Pb zircon SHRIMP ages, geochemical and Sr-Nd-Pb isotopic compositions of intrusive rocks from the Longshan-Tianshui area in the southeast corner of the Qilian orogenic belt, China: Constraints on petrogenesis and tectonic affinity[J]. Journal of Asian Earth Sciences, 2006, 27(6): 751—764.

[113] Zhang H F, Zhang L, Harris N, Jin L L, Yuan H L. U-Pb zircon ages, geochemical and isotopic compositions of granitoids in Songpan-Garze fold belt, eastern Tibetan Plateau: Constraints on petrogenesis and tectonic evolution of the basement[J]. Contribution to Mineralogy and Petrology, 2006, 152: 75—88.

[114] 张海祥，牛贺才，Hiroaki Sato，单强，于学元，Jun'ichi Ito，张旗. 新疆北部晚古生代埃达克岩、富铌玄武岩组合：古亚洲洋板块南向俯冲的证据[J]. 高校地质学报，2004，10(1)：106—113.

Zhang Haiyang, Niu Hecai, Hiroaki Sato, Shan Qiang, Yu Xueyuan, Jun'ichi Ito, Zhang Qi. Late Paleozoic adakite and Nb-enriched basalt from northern Xinjiang: Evidence for the southward subduction of the paleo-Asian Ocean[J]. Geological Journal of China Universities, 2004, 10(1): 106—113. (in Chinese with English abstract)

[115] Zhang H X, Niu H C, Sato H, Yu X Y, Shan Q, Zhang B Y, Ito J, Nagao T. Late Paleozoic adakites and Nb-enriched basalts from northern Xinjiang, northwest China: Evidence for the southward subduction of the Paleo-Asian Oceanic Plate[J]. The Island Arc, 2005, 14: 55—68.

[116] 张炯飞，李之彤，金成洙. 中国东北部地区埃达克岩及其成矿意义[J]. 岩石学报，2004，20(2)：361—368.

Zhang Jiongfei, Li Zhitong, Jin Chengzhu. Adakites in northeastern China and their mineralized implications[J]. Acta Petrologica Sinica, 2004, 20(2): 361—368. (in Chinese with English abstract)

[117] 张炯飞，庞庆邦，朱群，金成洙. 试论与埃达克岩有关的热液矿床成因类型和成矿系列——以中国北方若干矿床为例[J]. 地质与资源，2003，12(3)：171—176.

Zhang Jiongfei, Pan Qingbang, Zhu Qun, Jin Chengzhu. Genetic types and Metallogenic series of the hydrothermal deposits related to adakites: A case study of some deposits in Northern China[J]. Geology and Resource, 2003, 12 (3): 171—176. (in Chinese with English abstract)

[118] 张连昌，秦克章，英基丰，夏斌，舒建生. 东天山土屋. 延东斑岩铜矿带埃达克岩及其与成矿作用的关系[J]. 岩石学报，2004，20(2)：259—268.

Zhang Lianchang, Qin Kezhang, Ying Jifeng, Xia Bin, Shu Jiansheng. The relationship between ore-forming processes and adakitic rock in Tuwu-Yandong porphyry copper metallogenic belt, eastern Tianshan mountains[J]. Acta Petrologica Sinica, 2004, 20 (2): 259—268. (in Chinese with English abstract)

[119] 张连昌，万博，焦学军，张锐. 西准包古图含铜斑岩的埃达克岩特征及其地质意义[J]. 中国地质，2006，33(3)：626—631.

Zhang Lianchang, Wan Bo, Jiao Xuejun, Zhang Rui. Characteristics and geological significance of adakitic rocks in copper-bearing porphyry in Baogutu, western Junggar[J]. Geology in China, 2006, 33(3): 626－631. (in Chinese with English abstract)

[120] 张连昌，万博，李文铅，唐红峰. 新疆吐哈盆地南缘铜矿带含矿斑岩的地球化学及形成环境[J]. 岩石学报，2006，22(1)：225－235.
Zhang Lianchang, Wan Bo, Li Wenqian, Tang Hongfeng. Geochemistry and tectonic setting of copper-bearing porphyries on the southern margin of tuba basin, xinjiang[J]. Acta Petrologica Sinica, 2006, 22(1): 225－235. (in Chinese with English abstract)

[121] Zhang L C, Xiao W J, Qin K Z, Zhang Q. The adakite connection of the Tuwu-Yandong copper porphyry belt, eastern Tianshan, NW China: Trace element and Sr-Nd-Pb isotope geochemistry[J]. Mineralium Deposita, 2006, 41: 188－200.

[122] 张永北，孙世华，毛骞. 大兴安岭南段东麓中生代O型埃达克质火山岩及其成因、古构造环境和找矿意义[J]. 岩石学报，2006，22(9)：2289－2304.
Zhang Yongbei, Sun Shihua, Mao Qian. Mesozoic O-type adakitic volcanic rocks and its petrogenesis, paleo-tectonic dynamic and mineralization significance of the eastern side of southern Da Hinggan, China[J]. Acta Petrologica Sinica, 2006, 22 (9): 2289－2304. (in Chinese with English abstract)

[123] 张永清，张有宽，郑宝军，徐国权，韩建刚，母吉君，张履桥. 内蒙古中部小南沟－明星沟地区新太古代大岩系及其地质意义[J]. 岩石学报，2006，22(11)：2762－2768.
Zhang Yongqing, Zhang Youkuan, Zheng Baojun, Xu Guoquan, Han Jiangang, Mu Jijun, Zhang Lüqiao. Geological character and significance of adakite and TTG in Xiaonagou-Mingxinggou district in central of Inner Mogolia[J]. Acta Petrologica Sinica, 2006, 22(11): 2762－2768. (in Chinese with English abstract)

[124] 赵振华，白正华，熊小林，梅厚钧，王一先. 西天山北部晚古生代火山-浅侵位岩浆岩$^{40}Ar/^{39}Ar$同位素定年[J]. 地球化学，2003，32(4)：317－327
Zhao Zhenhua, Bai Zhenghua, Xiong Xiaolin, Mei Houjun, Wang Yixian. $^{40}Ar/^{39}Ar$ chronological study of Late Paleozoic volcanic-hypabyssal igneous rocks in western Tianshan, Xinjiang[J]. Geochimica, 2003, 32(4): 317－327. (in Chinese with English abstract)

[125] 赵振华，王强，熊小林，张海祥，牛贺才，许继峰，白正华，乔玉楼. 新疆北部的两类埃达克岩[J]. 岩石学报，2006，22(5)：1249－1265.
Zhao Zhenhua, Wang Qinag, Xiong Xiaolin, Zhang Haixiang, Niu Hecai, Xu Jifeng, Bai Zhenghua, Qiao Yulou. Two types of adakites in north Xinjiang, China[J]. Acta Petrologica Sinica, 2006, 22(5): 1249－1265. (in Chinese with English abstract)

[126] Zhou M F, Yan D P, Wang C L, Liang Q, Allen Kennedy. Subduction-related origin of the 750 Ma Xuelongbao adakitic complex (Sichuan Province, China): Implications for the tectonic setting of the giant Neoproterozoic magmatic event in South China[J]. Earth Planet. Sci. Lett., 2006, 248 (1－2): 286－300.

[127] 朱弟成，潘桂棠，段丽萍，夏林，廖忠礼，王立全. 埃达克岩研究的几个问题[J]. 西北地质，2003，36(2)：13－19.
Zhu Dicheng, Pan Guitang, Duan Liping, Xia Lin, Liao Zhongli, Wang Liquan. Some problems in the research of adakite[J]. Northwestern Geology, 2003, 36(2): 13－19. (in Chinese with English abstract)

[128] 朱群，李之彤，王恩德，赵春荆. 吉林中部晚三叠世南楼山组埃达克岩与官马金矿床[J]. 地质与资源，2004，13(3)：137－142.
Zhu Qun, Li Zhitong, Wang Ende, Zhao Chunjing. The adakite of late Triassic Nanloushan formation and Guanma gold deposit in Central Jilin Province[J]. Geology and Resources, 2004, 13(3). 137－142. (in Chinese with English abstract)

[129] 朱迎堂，伊海生，王强，杨延兴，郭通珍，彭伟青. 海西金乌兰还东河中二叠世埃达克岩的发现及其意义[J]. 沉积与特提斯地质，2004，24(2)：30－34.
Zhu Yingtang, Yi Haisheng, Wang Qiang, Yang Yanxing, Guo Tongzhen, Peng Weiqing. The discovery and significance of the Middle Permian adakites along the Huandong River north of the Xijie Ulan lake, Qinghai[J]. Sedimentary Geology and Tethyan Geology, 2004, 24(2): 30－34. (in Chinese with English abstract)

[130] 张旗，王焰，钱青，翟明国，金惟浚，王元龙，简平. 晚太古代 Sanukite(赞岐岩)与地球早期演化[J]. 岩石学报，2004，20(6)：1355－1362.
Zhang Qi, Wang Yan, Qian Qing, Zhai Mingguo, Jin Weijun, Wang Yuanlong, Jian Ping. Sanukite of late Archaean and early Earth evolution[J]. Acta Petrologica Sinica, 2004, 20(6): 1355－1362. (in Chinese with English abstract)

[131] 张旗，钱青，翟明国，金惟浚，王焰，简平，王元龙. Sanukite(赞岐岩)的地球化学特征、成因及其地球动力学意义[J]. 岩石矿物学杂志，2005，24(2)：117－125.
Zhang Qi, Qian Qing, Zhai Mingguo, Jin Weijun, Wang Yan, Jian Ping, Wang Yuanlong. Geochemistry, petrogenesis and geodynamic implications of sanukite[J]. Acta Petrologica et Mineralogica, 2005, 24(2): 117－125. (in Chinese with English abstract)

[132] Defant M J, Richerson M, De Boer J Z, Strwart R H, Maury R C, Bellon H, Drummond M S, Jackson T E. Dacite genesis via both slab melting and differentiation: Petrogenesis of La Yeguada volcanic complex. Panama[J]. J. P., 1991, 32: 1101－1142.

[133] Kepezhinskas P K, Defant M J, Drummond M. Progressive enrichment of island arc mantle by melt-peridotite interaction inferred from Kamchatka xenoliths[J]. Geochim. Cosmochim. Acta, 1996, 60: 1217－1229.

[134] 李伍平. 辽西北票早侏罗世兴隆沟组英安岩的地球化学特征[J]. 岩石学报，2006，22(6)：1608－1616.

Li Wuping. Geochemical characteristics of the early Jurassic dacites of the Xinglonggou Formation in Beipiao area, west Liaoning Province[J]. Acta Petrologica Sinica, 2006, 22(6): 1608—1616. (in Chinese with English abstract)

[135] Xu W L, Gao S, Wang Q H, Wang D Y, Liu Y S. Mesozoic crustal thickening of the eastern North China craton: Evidence from eclogite xenoliths and petrologic implications[J]. Geology, 2006, 34: 721—724.

[136] Jiang Y H, Jiang S Y, Ling H F, Dai B Z. Low-degree melting of a metasomatized lithospheric mantle for the origin of Cenozoic Yulong monzogranite-porphyry, east Tibet: Geochemical and Sr-Nd-Pb-Hf isotopic constraints[J]. Earth Planet. Sci. Lett., 2006, 241(3—4): 617—633.

[137] Li J W, Ma C Q, Zhao X F, Zhou M F. Geochronology and petrogenesis of the Late Mesozoic adakitic intrusive rocks from Daye, eastern China: Impliaction for geodynamics[A]. Abstracts for Conference on Chinese Petrology and Geodynamics[C]. Nov. 1—6, 2006, Nanjing. 140—141.

[138] 续海金，马昌前. 实验岩石学对埃达克岩成因的限定——兼论中国东部富钾高 Sr/Y 比值花岗岩类[J]. 地学前缘，2003, 10(4): 417—427.
Xu Haijin, Ma Changqian. Constraints of experimental petrology on the origin of adakites, and petrogenesis of Mesozoic K-rich and high Sr/Y ratio granitoids in eastern China[J]. Earth Science Frontiers, 2003, 10: 417—427. (in Chinese with English abstract)

[139] Xiong X L, Adam J, Green T H. Rutile stability and rutile/melt HFSE partitioning during partial melting of hydrous basalt: Implications for TTG genesis[J]. Chem. Geol., 2005, 210: 339—359.

[140] Xiong X L, Adam J, Green T H. Trace element characteristics of partial melts produced by melting of metabasalts at high pressures: Constraints on the formation condition of adakitic melts[J]. Science in China (series D), 2006, 49: 915—925.

[141] Xiong X L, Xia B, Xu J F, Niu H C, Xiao W S. Na depletion in modem adakites via melt/rock reaction within the sub-arc mantle[J]. Chem. Geol., 2006, 229: 273—292.

[142] 刘红涛，张旗，刘建明，叶杰，曾庆栋，于昌明. 埃达克岩与 Cu、Au 成矿作用:有待深入研究的岩浆成矿关系[J]. 岩石学报，2004, 20(2): 205—218.
Liu Hongtao, Zhang Qi, Liu Jianming, Ye Jie, Zeng Qingdong, Yu Changming. Adakite versus porphyry copper and epithermal gold deposits: A possible metallogenetic specialization of magmatism required in-deep assessment[J]. Acta Petrologica Sinica, 2004, 20(02): 205—218. (in Chinese with English abstract)

[143] 芮宗瑶，侯增谦，李光明，张立生，王龙生，唐索寒. 俯冲、碰撞、深断裂和埃达克岩与斑岩铜矿[J]. 地质与勘探，2006, 42(1): 1—6.
Rui Zongyao, Hou Zengqian, Li Guangming, Zhang Lisheng, Wang Longsheng, Tang Suohan. Subduction, collision, deep fracture, adakite and porphyry copper deposit [J]. Geology and Prospecting, 2006, 42(1): 1—6. (in Chinese with English abstract)

[144] Zhang H, Zhang Q. Rare earths, trace element characteristics of high-Mg volcanic rocks of Yixian Formation in Sihetun west Liaoning Province and its apocalypse[J]. Journal of Rare Earths, 2005, 23(4): 502—506.

[145] 张静. 埃达克岩及其成矿作用和相关问题的讨论[J]. 矿物岩石地球化学通报，2003, 22(4): 365—371.
Zhang Jing. Discussion on adakite, its ore-bearing potential and some other related issues[J]. Bulletin of Mineralogy, Petrology and Geochemistry, 2003, 22(4): 365—371. (in Chinese with English abstract)

[146] 张旗，王焰，王元龙. 埃达克岩与构造环境[J]. 大地构造与成矿学，2003, 27(2): 101—108.
Zhang Qi, Wang Yan, Wang Yuanlong. On the relationship between adakite and its tectonic setting[J]. Geotectonica et Metallogenia, 2003, 27(2): 101—108. (in Chinese with English abstract)

[147] 张旗，秦克章，王元龙，张福勤，刘红涛，王焰. 加强埃达克岩研究，开创中国 Cu、Au 等找矿工作的新局面[J]. 岩石学报，2004, 20(2): 195—204.
Zhang Qi, Qin Kezhang, Wang Yuanlong, Zhang Fuqin, Liu Hongtao, Wang Yan. Study on adakite broadened to challenge the Cu and Au exploration in China[J]. Acta Petrologica Sinica, 2004, 20(2): 195—204. (in Chinese with English abstract)

[148] 张旗，秦克章，许继峰，刘红涛，王元龙，王焰，贾秀琴，韩松. 中国与埃达克质岩有关的矿床分布、找矿方向及找矿方法刍议[J]. 华南地质与矿产，2004, (2): 1—8.
Zhang Qi, Qin Kezhang, Xu Jifeng, Liu Hongtao, Wang Yuanlong, Wang Yan, Jia Xiuqin, Han Song. Discussion of distribution, prospecting principle and method for deposits related to adakites in China[J]. Geology and Mineral Resources of South China, 2004, (2): 1—8. (in Chinese with English abstract)

[149] 张旗，金惟俊，王元龙，李承东，王焰，贾秀勤. 大陆下地壳拆沉模式初探[J]. 岩石学报，2006, 22(2): 265—276.
Zhang Qi, Jin Weijun, Wang Yuanlong, Li Chengdong, Wang Yan, Jia Xiuqin. A model of delamination of continental lower crust[J]. Acta Petrologica Sinica, 2006, 22(2): 265—276. (in Chinese with English abstract)

[150] Rapp R P, Watson E B, Miller C F. Partial melting of amphibolite/eclogite and the origin of Archean trondhjemites and tonalites[J]. Precambrian Research, 1991, 51: 1—25.

[151] Rapp R P, Watson E B. Dehydration melting of metabasalt at 8—32 kbar: Implications for continental growth and crust-mantle recycling[J]. J. Petrol., 1995, 36: 891—931.

[152] 张旗，金惟俊，王元龙，李承东，贾秀勤. 晚中生代时中国东部高原北界探讨[J]. 岩石学报，2007, 23(3): 689—700.
Zhang Qi, Jin Weijun, Wang Yuanlong, Li Chengdong, Jia Xiuqin. Discussion of north boundary of the East China Plateau during late Mesozoic Era[J]. Acta Petrologica Sinica, 2007, 23(3): 689—700. (in Chinese with English abstract)