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埃达克质岩的构造背景与岩石组合

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摘 要:本文介绍了埃达克质岩形成的构造背景与岩石组合。埃达克质岩可以形成于不同的构造背景并与不同类型的岩石同时出现:1) 火山弧环境中常出现埃达克质岩-高镁安山岩-富 Nb 玄武质岩组合,它的形成可能与板片熔融以及熔体-地幔橄榄岩的相互作用有关;2) 大陆活动碰撞造山带环境(如羌塘)中埃达克质岩常与同期钾质或橄榄玄粗质岩共生,这可能与俯冲陆壳熔融和俯冲陆壳熔体交代的地幔橄榄岩熔融有关;3) 造山带伸展垮塌环境(如大别山)中埃达克质岩会伴随有镁铁质-超镁铁质岩浆出露,增厚下地壳产生埃达克质岩浆后的榴辉岩质残留体拆沉进入地幔,与地幔橄榄岩的混合可能形成后期镁铁质-超镁铁质岩浆的源区;4) 大陆板内伸展环境中埃达克质岩常与同期橄榄玄粗质的岩石共生,增厚、拆沉下地壳,以及富集地幔的熔融或岩浆混合在岩石的成因中发挥了重要作用。

关 键 词:埃达克质岩; 构造背景; 岩石组合; 地球动力学
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Tectonic Setting and Associated Rock Suites of Adakitic Rocks

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Abstract: In this paper, tectonic setting and associated rock suites of adakitic rocks are introduced. Adakitic rocks can be generated in different tectonic setting and occur together with some other types of magmatic rocks. In a volcanic arc setting, adakitic rock-high-Mg andesite-Nb-enriched basaltic rock suites often occur and are possibly derived by slab melting and the interaction between slab melt and mantle peridotites. In an active collisional orogenic belt (e.g. Qiangtang), adakitic rocks occur together with coeval potassic or shoshonitc rocks, and their petrogenesis is related to partial melting of subducted continental crust and mantle peridotites metasomatized by subducted continental crust-derived melts. In a collapsed and extensional stage of an orogenic belt (e.g., Dabie), adakitic rocks sometimes are followed by mafic-ultramafic rocks, which possibly originated from a mixed source comprising eclogitic residue that was formed after the extraction of adakitic magma in the lower crust and mantle peridotites. In an extensional setting within a continent, some adakitic rocks are associated with coeval shoshonitic rocks, and partial melting of thickened or delaminated lower crust and enriched mantle or magmatic mixing play an important role in their petrogenesis.

Key words: adakitic rocks; tectonic setting; rock suite; geodynamics

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“埃达克岩(adakites)”命名于1990年,最初被认为是一种由俯冲的年轻且热的洋壳在榴辉岩相条件下熔融形成的一类具特殊地球化学特征的中酸性火成岩。概念提出来之后受到广泛关注,也引起了争议。越来越多的研究发现,具有与埃达克岩类似地球化学特征的岩石,不仅可以出现在火山弧环境,也可以大量出现在非弧(大陆碰撞活动造山带、造山带伸展垮塌、大陆板内伸展等)环境。其成因也比较复杂,并不仅仅限于俯冲洋壳的熔融,可能还包括分离结晶、岩浆混合、增厚(或拆沉)下地壳的熔融、俯冲陆壳熔融、地幔熔融等等[2,3]。因此,“埃达克岩”命名的科学性颇受质疑。我们认为,埃达克岩的原始概念中最核心的要素,应该是这些地球化学特征:SiO_2 ≥56%,Al_2O_3 ≥15%,亏损Y(≤18 μg/g)和重稀土元素(HREE)(如Yb ≤1.9 μg/g),高的Sr(很少<400 μg/g),无或正Eu、Sr异常,贫高场强元素(HFSE)。我们把具有上述地球化学特征的岩浆岩称为“埃达克质(adakitic)岩”,而不考虑其成因、构造背景及其他地球化学特征(如K_2O、MgO含量和同位素比值等)[3]。最近我们总结了埃达克质岩的概念、金属成矿作用[3]。本文将重点介绍产于不同构造背景中埃达克质岩的形成机制和岩石组合。

1 火山弧环境

俯冲洋壳能否熔融形成中酸性岩浆岩是个长期争议的问题。1968年,Green和Ringwood[4]通过熔融实验提出了形成钙碱性中酸性火成岩的两种可能模式:1)进入地幔100～150 km深处的榴辉岩(源岩为大洋玄武岩MORB)的熔融;2)堆积(pile)玄武岩的下部熔融,源区残留物为辉石+斜长石+少量石榴子石。Kay[5]通过对美国阿留申群岛中Adak(埃达克)岛上新生代强烈亏损HREE(Yb<1.00 μg/g,La/Yb ≥40)且高MgO(≥4.50%)安山岩的研究,认为该安山岩是由俯冲的玄武质洋壳在榴辉岩相条件下熔融形成的岩浆与地幔楔橄榄岩发生交换反应后形成。但是Gill[6]认为绝大多数火山弧钙碱性玄武岩-安山岩-英安岩-流纹岩不可能由俯冲的MORB在榴辉岩相条件下熔融而成,因为洋壳在俯冲过程中被加热到其熔点前已经发生明显的脱水,因此上述弧火山岩更可能是由俯冲洋壳释放的流体所交代的地幔楔熔融所致。这一观点解释了绝大多数火山弧钙碱性火成岩的成因,并成为当时的主流学派。但是俯冲洋壳熔融形成强烈亏损HREE的太古宙TTG的模式仍然得到一些研究者的支持[7,8]。1990年,Defant和Drummond[1]发现,新生代火山弧中俯冲的年轻(≤25 Ma)且热的玄武质洋壳与一些具特殊地球化学特征的岩石密切共生,他们认为这些岩石是俯冲的年轻(≤25 Ma)且热的玄武质洋壳熔融所致,并将其命名为“埃达克岩”。年轻(≤25 Ma)且热的玄武质洋壳在俯冲过程中发生大规模脱水之前很容易达到熔点[9],这也解决了俯冲洋壳能否发生熔融的关键问题。但是,新生代火山弧中,一些埃达克质岩并不与俯冲的年轻(≤25 Ma)且热的玄武质洋壳共生[10]。于是,许多学者针对火山弧环境中埃达克质岩产生的动力学机制展开了热烈的讨论。归纳起来,有以下三种主要观点。

(1)主张俯冲的年轻的(≤25 Ma)或老的(≥25 Ma)板片可以发生熔融形成埃达克质岩。为了解决俯冲板片特别是老的(≥25 Ma)板片的熔融机制问题,相继提出了一些新的动力学模式:1)先前俯冲并残留于地幔中板片被地幔加热并发生熔融[11];2)倾斜的或快速俯冲的老的洋壳由于剪切加热而发生熔融[9];3)冷的板片在俯冲的开始阶段被加热并发生熔融[9,12];4)撕裂板片的边缘被加热而发生熔融[13];5)平坦俯冲的板片被加热而发生熔融[14];6)洋脊俯冲导致的板片窗加热板片的边缘发生熔融[15,16]。我们最近认为新疆北部天山石炭纪和羌塘北部三叠纪的埃达克质岩的形成可能与俯冲的年轻洋壳或平坦俯冲的稍老的洋壳熔融有关[17～19]。

(2)否认俯冲洋壳熔融能形成埃达克质岩的学者认为,其他机制也可能形成这样的岩石,这些机制主要有:1)来自地幔楔的玄武质岩浆底侵导致下地壳增厚并发生熔融[9,20];2)来自地幔楔的玄武质岩浆被地壳混染并发生低压分离结晶(AFC过程)[21];3)来自地幔楔的玄武质岩浆发生高压分离结晶作用[22];4)熔融-混染-存储(storage)-均化(MASH)过程[23]。

(3)不排除俯冲洋壳的熔融形成埃达克质岩,但认为一些与俯冲洋壳Nd-Sr同位素成分有明显差异的岩石可能由于其他机制熔融而成,这些机制包括:1)拆沉的火山弧下地壳的熔融[24,25];2)增厚下地壳与通过俯冲侵蚀进入到地幔中的下地壳物质的熔融[26]。

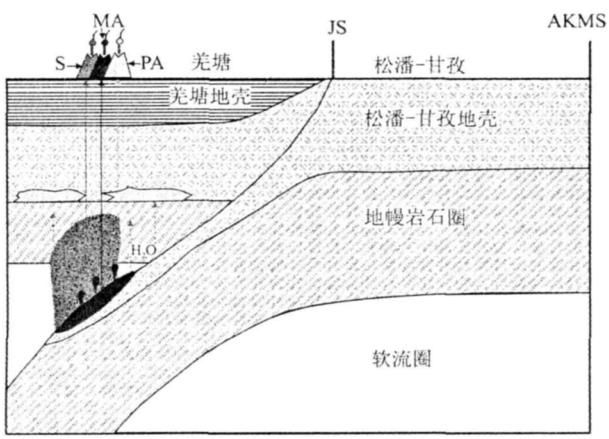
在火山弧带,埃达克质岩常与高镁安山岩、富Nb玄武质岩同时出现。部分研究者认为这些岩石与俯冲洋壳的熔融无关[27,28],但许多研究者则强调:该套岩石组合可能不同于传统上的弧岩浆岩——由俯冲洋壳释放的流体交代的地幔楔橄榄岩

熔融形成的玄武岩-安山岩-流纹岩组合,而可能为俯冲洋壳熔融所形成的熔体交代地幔楔橄榄岩后产生的"埃达克岩-高镁安山岩-富 Nb 玄武质岩组合"[12,16,17～19,30]。

2 大陆活动碰撞造山带环境

青藏高原是世界上最大、最高的高原,也是陆—陆碰撞形成的最典型的碰撞造山带。印度-欧亚大陆的碰撞约始于 70～40 Ma,大量的 GPS 资料显示两大陆间的汇聚现今仍在进行,表明它为一典型的活动造山带。最近报道该带产有大量新生代埃达克质岩,但其成因众说纷纭:1)地幔加热导致增厚下地壳熔融[30～35];2)俯冲陆壳流体加入导致增厚下地壳熔融[36];3)增厚下地壳熔融与幔源、上地壳物质的加入[37];4)滞留洋壳熔融[38,39];5)滞留洋壳+沉积物熔融[40];6)富集地幔的低度熔融[41];7)俯冲板片熔体交代的地幔发生熔融[42];8)拆沉下地壳熔融[43,44];9)俯冲含沉积物的陆壳熔融[45]。

除了新生代埃达克质岩外,青藏高原还产有大量同期钾质或橄榄玄粗质(shoshonitic)岩石。这些岩石与埃达克质岩的关系如何?针对羌塘北部始新世(46～38 Ma)紧密共生的低镁过铝质埃达克质岩-高镁准铝质埃达克质岩-橄榄玄粗质岩密切共生的现象,我们提出一个模式(图 1)来解释其成因[45]:低镁过铝质埃达克质岩由新生代俯冲的包含沉积物的大陆地壳在相对较浅的位置(角闪石+石榴子石稳定区)熔融而成,准铝质高镁埃达克质岩石(类似高镁安山岩)是在俯冲陆壳在较深的位置(石榴子石+金红石稳定区)发生熔融产生的熔体和地幔相互作用的结果,而俯冲陆壳产生的熔体交代的地幔橄榄岩发生熔融形成了同期的橄榄玄粗质岩。



S. 钾玄质岩石;MA. 准铝质埃达克质岩(包括埃达克质高镁安山岩);PA. 过铝质埃达克质岩;JS. 金沙江缝合线;AKMS. 阿尼玛卿-昆仑-木孜塔格缝合线

S. shoshonitic rocks; MA. metaluminous adakitic rocks; PA. peraluminous adakitic rocks; JS. Jinshajiang; AKMS. Anyimaqen-Kunlun-Muztagh

图 1 羌塘北部始新世火山岩形成的示意图[45]

Fig. 1 A suggested model to produce Eocene igneous rocks in the Northern Qiangtang area[45]

3 造山带伸展垮塌环境

一个活动造山带何时进入伸展垮塌阶段没有统一的标准。但是三叠纪扬子-华北地块碰撞形成的大别-苏鲁造山带在白垩纪明显处于一个伸展的阶段,重要证据是出露有白垩纪北大别变质核杂岩和 A 型花岗岩。一些研究者相继报道大别地区有白垩纪的埃达克质花岗岩[46～49]。我们最近在大别山北部白垩纪变质核杂岩的核部发现了早白垩世(143～129 Ma)的埃达克质花岗岩,它们具有极低的 MgO、Ni 含量和类似于大别-苏鲁造山带三叠纪榴辉岩的 Nd-Sr 同位素组成[50]。我们认为北大别埃达克质花岗岩由增厚的含角闪石或金红石的榴辉岩质下地壳熔融而成,埃达克质花岗岩形成后,源区的榴辉岩质残留体发生下地壳拆沉作用,岩石圈拆沉后的软流圈上涌为大别地区早白垩世岩浆提供了热量。

大别地区还有大量 130～123 Ma 的镁铁质-超镁铁质岩[51,52],它们略微晚于埃达克质花岗岩[50]。我们认为,产生埃达克质花岗质岩浆后的榴辉岩质残留体拆沉进入地幔,与地幔橄榄岩混合,成为后期"富集型"镁铁质-超镁铁质岩浆的源区[50]。

4 大陆板内伸展环境

除了墨西哥中部始新世埃达克质岩[53]之外,国际上报道的陆内伸展背景下的埃达克质岩并不多。我们近年研究了一个典型地区——扬子地块东部。根据区内燕山期变质核杂岩、A 型或伸展型岩浆岩以及断陷盆地的分布,认为该区燕山期可能处于板内伸展背景[54,55],断裂带在岩浆岩的形成中可能发挥了重要作用[56]。许多研究者也识别出许多燕山期的埃达克质岩,并提出了一些不同的成因机制:1)增厚下地壳的熔融[57];2)拆沉下地壳的熔融[58～60];3)分离结晶作用[61];4)富集地幔的低度熔融[62,63];5)岩浆混合[64];6)残留洋壳的熔融[59]。

扬子地块东部除了出露燕山期特别是白垩纪的埃达克质岩外,还出现大量白垩纪的橄榄玄粗质岩[65]。传统的埃达克质-橄榄玄粗质岩组合主要产

于岛弧环境[1],但扬子地块东部这两种类型完全不同的岩石同时出现究竟有什么成因联系?我们最近通过对安徽庐枞地区埃达克质岩与橄榄玄粗质岩石的研究表明[60],这两类岩石是一套大陆板内的埃达克质岩-橄榄玄粗质岩组合:埃达克质岩是拆沉下地壳在大于 50 km(即约 1.5 GPa)条件下熔融而成,并在源区留下了含金红石的榴辉岩残留体;橄榄玄粗质岩起源于俯冲沉积物交代的富集地幔,但岩浆在上升过程中经历了早期在壳幔边界的高压(1.5 GPa 以上)分离结晶和晚期地壳浅处(50 km 以浅)低压(1.5 GPa 以下)的分离结晶;最晚期的响岩-粗面岩可能有一些来自亏损的软流圈地幔或含金红石的榴辉岩残留体的熔体加入。中国东部晚中生代岩石圈地幔的减薄和热的软流圈地幔沿北东向断裂带(如郯庐或长江断裂带)上升,导致富集地幔和拆沉下地壳熔融,从而形成了一套板内的埃达克质-橄榄玄粗质岩组合[60]。

5 问题与小结

埃达克质岩的成因还有诸多争论,成因模式已达十多种,而且即使构造背景、地区或形成时代相同的埃达克质岩,其成因机制也有不同的认识。另外,本文虽然根据构造背景来介绍埃达克质岩的成因、岩石组合,但构造背景的划分标准还有待深入研究。近年来的研究启发我们认识到埃达克质岩可以形成于多种构造背景,并具有多种成因方式。

参考文献(References):

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

[2] 王强, 许继峰, 赵振华, 资锋, 唐功建, 贾小辉, 姜子琦. 中国埃达克岩或埃达克质岩及相关金属成矿作用[J]. 矿物岩石地球化学通报, 2007, 26(4): 336 - 349.
Wang Qiang, Xu Jifeng, Zhao Zhenhua, Zi Feng, Tang Gongjian, Jia Xiaohui, Jiang Ziqi. Adakites or adakitic rocks and associated metal metallogenesis in China [J]. Bulletin of Mineralogy, Petrology and Geochemistry, 2007, 26(4): 336 - 349. (in Chinese with English abstract)

[3] 王强, 唐功建, 贾小辉, 资锋, 姜子琦, 许继峰, 赵振华. 埃达克质岩的金属成矿作用[J]. 高校地质学报, 2008, 14 (3): 206 - 219.
Wang Qiang, Tang Gongjian, Jia Xiaohui, Jiang Ziqi, Xu Jifeng, Zhao Zhenhua. The metalliferous mineralization associatied with adakitic rocks[J]. Geol. J. China Univ., 2008, 14 (3): (206 - 219). (in Chinese with English abstract)

[4] Green T H, Ringwood A E. Genesis of the calc-alkaline igneous rocks suite [J]. Contrib. Mineral. Petrol., 1968, 18: 105 - 162.

[5] Kay R W. Aleutian magnesian andesites: Melts from subducted Pacific Ocean crust [J]. J. Volcanol. Geotherm. Res., 1978, 4: 117 - 132.

[6] Gill J B. Orogenic andesite and Plate tectonics[M]. Berlin: Springer, 1981.

[7] Condie K C. Archean greenstone belts[M]. Amsterdam: Elsevier, 1981: 434.

[8] Martin H. Effect of steeper Archean geothermal gradient on geochemistry of subduction-zone magmas [J]. Geology, 1986, 14: 753 - 756.

[9] Peacock S M, Rushmer T, Thompson A B. Partial melting of subducting oceanic crust[J]. Earth Planet. Sci. Lett., 1994, 121: 227 - 244.

[10] Atherton M P, Petford N. Generation of sodium-rich magmas from newly underplated basaltic crust [J]. Nature, 1993, 362: 144 - 146.

[11] Defant M J, Kepezhinskas P. Evidence suggests slab melting in arc magmas [J]. EOS, 2001, 82: 62 - 69.

[12] Sajona F G, Maury R C, Bellon H, Cotten J, Defant M J, Pubellier M. Initiation of subduction and the generation of slab melts in western and eastern Mindanao, Philippines [J]. Geology, 1993, 21: 1007 - 1010.

[13] Yogodzinski G M, Lees J M, Churikova T G, Doreneorf F, Woerner G, Volynets O N. Geochemical evidence for the melting of subducting oceanic lithosphere at plate edges [J]. Nature, 2001, 409:500 - 504.

[14] Gutscher M A, Maury R, Eissen J, Bourdon E. Can slab melting be caused by flat subduction? [J]. Geology, 2000, 28:535 —538.

[15] Abratis M, Worner G. Ridge collision, slab-window formation, and the flux of Pacific asthenosphere into the Caribbean realm [J]. Geology, 2001, 29: 127 - 130.

[16] Aguillon-Robles A, Calmus T, Benoit M, Bellon H, Maury R O, Cotten J, Bourgois J, Michaud F. Late miocene adakites and Nb-enriched basalts from Vizcaino Peninsula, Mexico: Indicators of East Pacific Rise subduction below Southern Baja California? [J]. Geology, 2001, 29(6): 531 - 534.

[17] 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)

[18] 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): Implications for Phanerozoic crustal growth in the Central Asia orogenic belt [J]. Chemical Geology, 2007, 236(1-2): 42-64.

[19] Wang Q, Wyman D A, Xu J F, Wan Y S, Li C F, Zi F, Jiang Z Q, Qiu H N, Chu Z Y, Zhao Z H, Dong Y H. Triassic Nb-enriched basalts, magnesian andesites, and adakites of the Qiangtang terrane (Central Tibet): Evidence for metasomatism by slab-derived melts in the mantle wedge[J]. Contrib. Mineral. Petrol., 2008, 155(4): 473-490.

[20] Zhao J H, Zhou M F. Neoproterozoic adakitic plutons in the northern margin of the Yangtze Block, China: Partial melting of a thickened lower crust and implications for secular crustal evolution[J]. Lithos, 2008, 104: 231-248.

[21] Castillo P R, Janney P E, Solidum R U. Petrology and geochemistry of Camiguin island, southern Philippines: Insights to the source of adakites and other lavas in a complex arc setting[J]. Contrib. Mineral. Petrol., 1999, 134: 33-51.

[22] Macpherson C G, Dreher S T, Thirlwall M F. Adakites without slab melting: High pressure differentiation of island arc magma, Mindanao, the Philippines[J]. Earth Planet. Sci. Lett., 2006, 243(3-4): 581-593.

[23] Richards J P, Kerrich R. Special Paper: Adakite-Like Rocks: Their diverse origins and questionable role in metallogenesis[J]. Economic Geology, 2007, 102(4): 537-576.

[24] Kay R W, Kay S M. Delamination and delamination magmatism[J]. Tectonophysics, 1993, 219: 177-189.

[25] Kay R W, Kay S M. Andean adakites: Three ways to make them[J]. Acta Petrologica Sinica, 2002, 18: 303-311.

[26] Kay S M, Godoy E, Kurtz A. Episodic arc migration, crustal thickening, subduction erosion, and magmatism in the south-central Andes[J]. Geol. Soc. Am. Bull., 2005, 117: 67-88.

[27] Castillo P R, Solidum R U, Punongbayan R S. Origin of high field strength element enrichment in the Sulu Arc, southern Philippines, revisited[J]. Geology, 2002, 30: 707-710.

[28] Castillo P R. Origin of the adakite-high-Nb basalt association and its implications for postsubduction magmatism in Baja California, Mexico [J]. Geol. Soc. Am. Bull., 2008, 120(3-4): 451-462.

[29] Defant M J, Kepezhinskas P, Defant M J, Xu J F, Kepezhinskas P, Wang Q, Zhang Q, Xiao L. Adakites: Some variations on a theme [J]. Acta Petrologica Sinica, 2002, 18: 129-142.

[30] **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[J]. Earth Science Frontiers, 10(4): 385-400. (in Chinese with English abstract)

[31] Lai S C, Lium C Y, Yi H S. Geochemistry and petrogenesis of Cenozoic andesite-dacite associations from the Hoh Xil Region, Tibetan Plateau [J]. Inter. Geol. Rev., 2003, 45(11): 998-1019.

[32] Lai S C, Qin J F, Li Y F. Partial melting of thickened Tibetan crust: Geochemical evidence from Cenozoic adakitic volcanic rocks[J]. Int. Geol. Rev., 2007, 49(4): 357-373.

[33] 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.

[34] 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.

[35] Guo Z F, Wilson M, Liu J Q. Post-collisional adakites in south Tibet: Products of partial melting of subduction-modified lower crust[J]. Lithos, 2007, 96(1-2): 205-224.

[36] 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.

[37] **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)

[38] 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.

[39] 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.

[40] 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.

[41] 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.

[42] 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]. Contrib. Mineral. Petrol., 2007, 153(1): 105-120.

[43] **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)

[44] Liu S, Hu R Z, Feng C X, Zou H B, Li CA I, Chi X G, Peng J T, Zhong H, Qi L, Qi Y Q, Wang T A O. Cenozoic high Sr/ Y volcanic rocks in the Qiangtang terrane, northern Tibet: geochemical and isotopic evidence for the origin of delaminated lower continental melts[J]. Geological Magazine, 2008, 145: 463 - 474.

[45] Wang Q, Wyman D A, Xu J, Dong Y, Vasconcelos P M, Pearson N, Wan Y, Dong H, Li C, Yu Y, Zhu T, Feng X, Zhang Q, Zi F, Chu Z. Eocene melting of subducting continental crust and early uplifting of central Tibet: Evidence from central-western Qiangtang high-K calc-alkaline andesites, dacites and rhyolites [J]. Earth Planet. Sci. Lett., 2008, 272: 158 - 171.

[46] **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 Jufeng, Zhao Zhenhua, Wang Renjing, Qiu Jiaxiang, Bao Ziwei. 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)

[47] 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.

[48] Xu H J, Ma C Q, Ye K. Early cretaceous granitoids and their implications for the collapse of the Dabie orogen, eastern China: SHRIMP zircon U-Pb dating and geochemistry [J]. Chemical Geology, 2007, 240(3 - 4): 238 - 259.

[49] Huang F, Li S, Dong F, He Y, Chen F. High-Mg adakitic rocks in the Dabie orogen, Central China: Implications for foundering mechanism of lower continental crust[J]. Chemical Geology, 2008, 255(1 - 2): 1 - 13.

[50] Wang Q, Wyman D A, Xu J, Jian P, Zhao Z, Li C, Xu W, Ma J, 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, 71(10): 2609 - 2636.

[51] **李曙光, 洪吉安, 李惠民, 江来利. 大别山辉石岩-辉长岩体的锆石 U-Pb 年龄及其地质意义**[J]. **高校地质学报**, 1999, 5(3): 351 - 355.
Li Shuguang, Hong Ji'an, Li Huimin, Jiang Laili. U-Pb zircon ages of the pyroxenite-gabbro intrusions in Dabie Mountains and their geological implications [J]. Geol. J. China Univ., 1999, 5(3): 351 - 355. (in Chinese, with English abstract)

[52] Zhao Z F, Zheng Y F, Wei C S, Wu Y B, Chen F K, Jahn B M. Zircon U-Pb age, element and C-O isotope geochemistry of post-collisional mafic-ultramafic rocks from the Dabie orogen in east-central China [J]. Lithos, 2005, 83: 1 - 28.

[53] Pinto-Linares P J, Levresse G, Tritlla J, Valencia V A, Torres-Aguilera J M, Gonzalez M, Estrada D. Transitional adakite-like to calc-alkaline magmas in a continental extensional setting at La Paz Au-Cu skarn deposits, Mesa Central, Mexico: Metallogenic implications [J]. Revista Mexicana De Ciencias Geologicas, 2008, 25(1): 39 - 58.

[54] Li X H. Cretaceous magmatism and lithospheric extension in Southeast China [J]. J. Asian Earth Sci., 2000, 18(3): 293 - 305.

[55] **王强, 赵振华, 简平, 熊小林, 包志伟, 戴橦模, 许继峰, 马金龙. 华南腹地白垩纪 A 型花岗岩类或碱性侵入岩年代学及其对华南晚中生代构造演化的制约** [J]. **岩石学报**, 2005, 21(3): 795 - 808.
Wang Qiang, Zhao Zhenhua, Jian Ping, Xiong Xiaolin, Bao Zhiwei, Dai Tangmu, Xu Jifeng, Ma Jinlong. Geochronology of Cretaceous A-type granitiods or alkaline intrusive rocks in the hinterland, South China: Constraints for late-Mesozoic tectonic evolution [J]. Acta Petrologica Sinica, 2005, 21(3): 795 - 808. (in Chinese with English Abstract)

[56] **周新民, 孙涛, 沈渭洲. 华南中生代花岗岩-火山岩的时空格局与成因模式**[A]. **陈骏. 地质与地球化学进展 ——庆祝王德滋院士致力于地质科学六十周年暨八十华诞**[C]. **南京: 南京大学出版社**, 2006: 25 - 40.
Zhou Xinmin, Sun Tao, Shen Weizhou. The space-age distribution and petrogenesis models of Mesozoic granitoidsand volcanic rocks in South China[A]. Chen Jun. The Progress in Geology and Geochemistry[C]. Nanjing: Nanjing University, Press, 2006: 25 - 40. (in Chinese)

[57] **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)

[58] 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.

[59] 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]. Journal of Petrology, 2006, 47(1): 119 - 144.

[60] 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.

[61] 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.

[62] Li J W, Zhao X F, Zhou M F, Vasconcelos P, Ma C Q, Deng X D, de Souza Z S, Zhao Y X, Wu G. Origin of the Tongshankou porphyry-skarn Cu-Mo deposit, eastern Yangtze craton, Eastern China: Geochronological, geochemical, and Sr-Nd-Hf isotopic constraints[J]. Mineralium Deposita, 2008, 43(3): 315 - 336.

[63] Xie G Q, Mao J W, Li R L, Bierlein F P. Geochemistry and Nd-Sr isotopic studies of Late Mesozoic granitoids in the southeastern Hubei Province, Middle-Lower Yangtze River belt, eastern China: Petrogenesis and tectonic setting [J]. Lithos, 2008.

[64] 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.

[65] 王德滋, 任启江, 邱检生, 陈克荣, 徐兆文, 曾家湖. 中国东部橄榄安粗岩省的火山岩特征及其成矿作用[J]. 地质学报, 1996, 70(1): 23 - 34.
Wang Dezi, Ren Qijiang, Qiu Jiansheng, Chen Kerong, Xu Zhaowen, Zeng Jiahu. Characteristica of volcanic rocks in the shoshonite province, eastern China, and their metallogenesis [J]. Acta Geologica Sinica, 1996, 70: 23 - 34. (in Chinese with English abstract)

·学会之声 ·

第五届全国油气储层学术研讨会在成都举行

第五届全国油气储层学术研讨会于 2008 年 8 月 28～31 日在四川省成都市召开。会议由中国地质学会沉积地质专业委员会、中国矿物岩石地球化学学会沉积学专业委员会主办,成都理工大学承办,中石油西南油气田分公司、中石化西南油气分公司、勘探南方分公司等单位协办。

此次学术研讨会共收到论文 132 篇。来自国内 12 家油田单位、16 所高校、11 家科研院所以及 5 家期刊出版单位 272 名代表与会。其中有中国科学院院士孙枢和刘宝珺,以及一大批在"沉积、储层"等领域中取得优异成绩的专家、学者。

大会开幕式上,成都理工大学校长刘家铎教授致热情洋溢的欢迎词。中国科学院孙枢院士、成都理工大学名誉校长刘宝珺院士、著名沉积学家曾允孚教授,以及中国石油西南油气田熊建嘉副总经理分别致辞。会议围绕"海相沉积与储层"这一主题,以大会和分组形式分别报告和研讨。

会议安排了 16 个大会报告,内容涉及海相油气勘探进展与面临的挑战、元古代全球古大陆和古海洋再造、碳酸盐岩储层进展及发展趋势、中国白垩纪大陆科学钻探工程、储层成岩作用的研究现状和方向、构造—层序岩相古地理编图、四川盆地 P - T 礁滩储层发育分布与预测、叠合盆地碳酸盐岩储层的构造因素、热液活动对碳酸盐岩储层的影响、成岩演化特征与相对优质储层成因、礁滩储层的地震响应特征和预测方法、碳酸盐成岩作用研究、地震沉积学、大气田古岩溶储层主控因素、塔河奥陶系储层结构的流体化学-动力学响应、五峰组观音桥段成因。

57 个分会报告重点讨论了海相沉积体系、岩相古地理、层序地层、储层特征与分布规律、储层形成与发育机理等科学问题。

与会代表就相关的研究领域进行了研讨与交流,他们绝大部分是青年"沉积、储层"科研工作者,有相当一部分来自各油田和科研第一线。他们掌握了大量第一手资料,朝气蓬勃,勇于实践、勇于探索,表现出较高的科学研究水平。

会议总结与交流了我国近年来在油气储层及相关地质、地球化学及地球物理等研究领域的最新研究成果,讨论了油气储层研究的现状、问题与发展趋势。本次学术研讨会的召开丰富了适合中国实际的海相石油地质理论,部分解决了困扰中国海相油气勘查问题,也研讨了拥有自主知识产权的核心技术,对从整体上提高中国油气储层研究和勘探的水平具有重要现实意义。

会议评选了沉积和储层研究方面的优秀学术论文,推荐给《成都理工大学学报》自然科学版和《天然气工业》予以发表。

(中国矿物岩石地球化学学会沉积学专业委员会 供稿)