西天山特克斯达坂库勒萨依序列埃达克岩的确立及钼找矿意义*

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Abstract　The porphyry assemblage of Kulesayi series is calc-alkaline hypabyssal rocks formed in island-arc environment with a mean value of $\delta = 3.05$ and a mean content of $SiO_2 = 57.06 \sim 70.74\%$. They are rich in Al_2O_3, Na_2O, Sr and LREE, and poor in MgO, Y, Yb and HREE. Their Na_2O/K_2O is larger than 1, Sr/Y is 57.67, Eu anomaly is positive, which indictes characters of O-type adakite. The porphyry assemblage of Kulesayi series from which Mo orebodies have been discovered correlates well with anomaly of Mo, therefore it has a good ore-prospecting future. The understanding of adakite rocks provides significant information for improving native metallogenic disciplinarian and guiding future ore-prospecting in western Tianshan.

Key words　Porphyry assemblage of Kulesayi series in Early Carboniferous; Adakite rocks; Significance of Mo prospecting; Tekesi Daban; Western Tianshan

摘　要　库勒萨依序列斑岩体δ平均3.05,属于钙碱性系列岛弧浅成岩。SiO_2含量为57.06% ~70.74%,高Al_2O_3、Na_2O、Sr和相对富集LREE,低MgO、Y、Yb,强烈亏损HREE。$Na_2O/K_2O > 1$,Sr/Y平均57.67,正Eu异常,因而具有典型O型埃达克岩特征。库勒萨依序列斑岩体与Mo异常套合好,已发现钼矿体,找矿前景良好。该埃达克岩的确立,对深化西天山区域成矿规律和指导今后找矿具有借鉴和指导意义。

关键词　早石炭世勒萨依序列斑岩;埃达克岩;钼找矿意义;特克斯达坂;西天山

中图法分类号　P618.65; P588.122

1　引言

伊犁—中天山地处准噶尔板块和塔里木板块的交汇处,其岩石圈动力学演化及其成矿作用是近年来国内外地学界的研究热点(李锦轶等,2006;赵振华等,2006;朱永峰等,2007;Zhu *et al.*, 2007)。自2000年以来,在西天山、东天山土屋—延东等地相继发现了埃达克岩,并探讨了其成矿作用(王强等,2003a, b,2006;赵振华等,2004;侯增谦等,2003)。赵振华等(2006)将新疆北部地区的埃达克岩划分为形成于泥盆纪—早石炭世(≥320Ma)的洋壳俯冲型和形成于中晚二叠世(≤280Ma)的玄武质岩浆底侵型两种类型。这两类埃达克岩的岩石学、地球化学及成矿作用特点均有一定的差异,对探讨区内岩石圈动力学演化及成矿作用均有十分重要的意义。天山地区早石炭世存在岛弧(姜常义等,1993,

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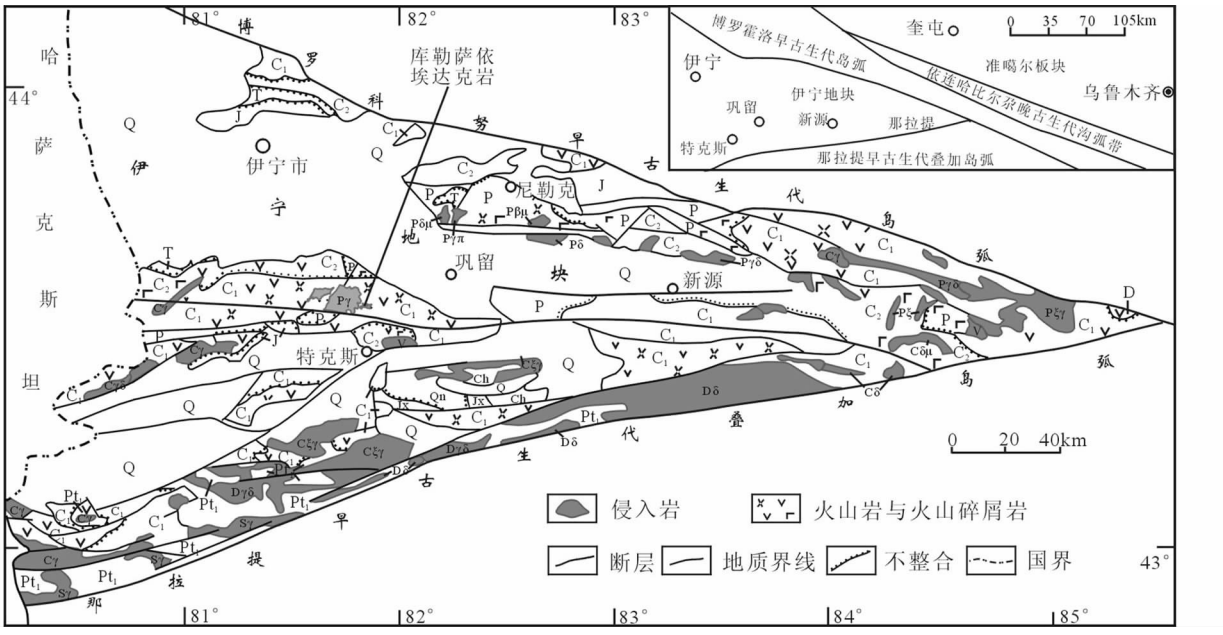


图 1 西天山地质构造简图(据新疆维吾尔自治区地质矿产局,1993,有改动)

Q-第四系;T-三叠系;P-二叠系;C-石炭系;D-泥盆系;Qn-青白口系;Jx-蓟县系;Ch-长城系;ν-辉长岩;βμ-辉绿岩;δ-闪长岩;δμ-闪长玢岩;γδ-花岗闪长岩;γ-花岗岩;γπ-花岗斑岩;ξγ-正长花岗岩;ξ-正长岩

Fig. 1 Geological tectonic sketch map of the Western Tianshan (after Bureau of Geology and Mineral Resources of Xinjiang Uygur Autonomous Region, 1993)

Q-Quaternary system; T-Tertiary system; P-Permian system; C-Carboniferous system; D-Devnian system; Qn-Qingbaikou system; Jx-Jixian system; Ch-Changcheng system; ν-gabbro; βμ-daibase; δ-diorite; δμ-diorite-porphyrite; γδ-granodiorite; γ-granite; γπ-granite-porphyry; ξγ-moyite; ξ-syenite

1995;李锦轶等,2006;李永军等,2007a,b,2008;朱永峰和宋彪,2006;朱永峰等,2005,2006a, b;Zhu *et al.*, 2006)和裂谷(车自成等,1994,1996;夏林圻等,2002;王京彬和徐新,2006)两种构造环境之争,库勒萨依 O 型埃达克支持岛弧构造环境。库勒萨依斑岩是作者等在进行 1∶5 万区域地质矿产调查中新发现和确立的一典型 O 型埃达克岩(李永军等,2007b),并于其中新发现了钼矿体。本文重点讨论这一含矿的 O 型埃达克岩地球化学特征及钼找矿意义。

2 地质背景

特克斯达坂位于西天山造山带伊宁—中天山板块腹地(成守德和王元龙,1998;新疆维吾尔自治区地质矿产局,1993;李锦轶等,2006。图 1)。泥盆纪末—石炭纪初,南天山洋向北俯冲于伊犁—中天山板块之下,造成了伊犁地块陆缘和岛弧早石炭世大规模的火山、岩浆侵入活动,库勒萨依斑岩体就是这一进程中的产物。南天山洋缝合的标志为沿图拉苏—那拉提山南缘断裂带分布的蛇绿岩和双变质带(陈哲夫和梁云海,1991;成守德和王元龙,1998)。北天山洋存在的最晚时期也是早石炭世,可能在此时已开始由北向南向伊犁地块之下俯冲,这样造成了南侧的陆缘和岛弧的火山活动,表现为大量的火山碎屑沉积岩和较少的溢流相熔岩,并且基性熔岩中有洋脊玄武岩。

石炭纪地层在区内出露最为广泛。依据作者最新研究成果,由 5 个组级岩石地层单位组成,各组间均为角度不整合接触关系(李永军等,2008)。由老到新依次为早石炭世大哈拉军山组钙碱性岛弧玄武安山岩—钠长斑岩—英安岩以及同质火山碎屑岩(李注苍等,2006)→早石炭世阿克沙克组以生物碎屑灰岩、钙质砂岩、粉砂岩为主的碳酸盐岩和碎屑岩组合(高永利等,2006)→晚石炭世伊什基里克组双峰式碱性系列玄武岩、钠长霏细斑岩、流纹岩及少量火山碎屑岩(刘静等,2006)→晚石炭世东图津河组海陆交互相砂岩—细砂岩夹砂砾岩及少量泥灰岩(张天继等,2006)→科古琴山组厚层砾岩等磨拉石建造。特克斯达坂一带最老的地层除早石炭世大哈拉军山组之外,局地还新发现有晚泥盆世特克斯达坂组钙碱性岛弧火山岩(362Ma,朱永峰等,2006a,b;Zhu *et al.*, 2006)。本文所讨论的库勒萨依斑岩呈小岩体和岩枝侵入于晚泥盆世—早石炭世的火山—沉积岩中,或呈捕虏体被包裹于早二叠世其那尔萨依岩体中(李永军等,2007a,b。图 2)。

3 岩石地球化学

库勒萨依埃达克岩由早期石英闪长玢岩和晚期花岗闪

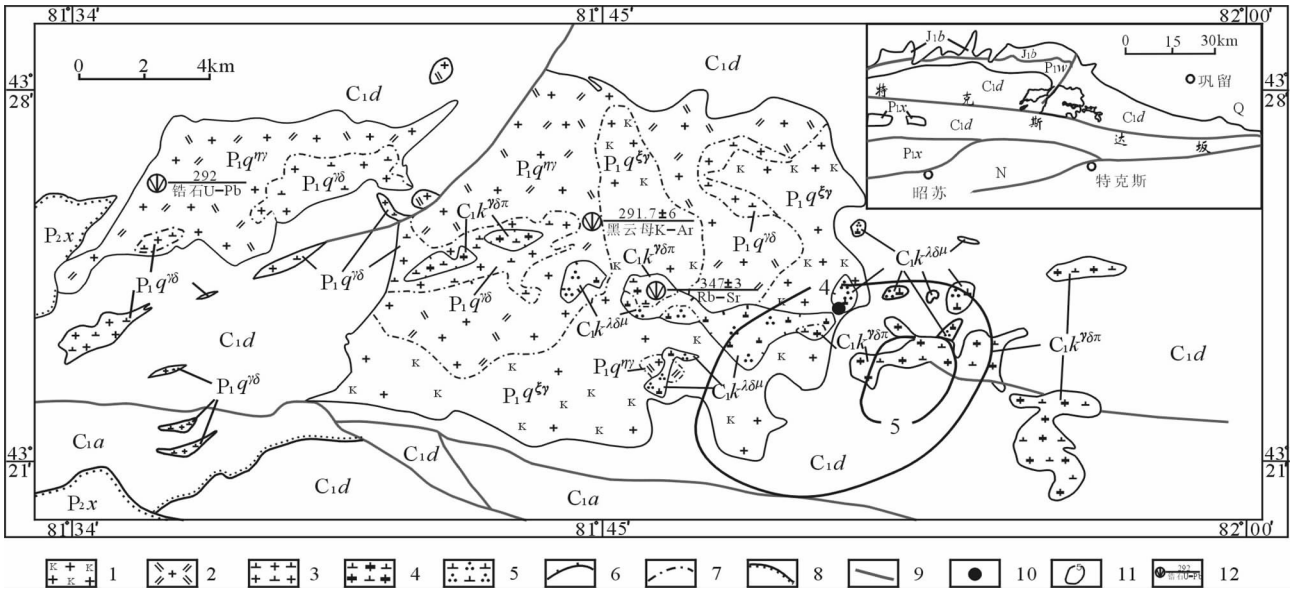


图 2 西天山特克斯达坂岩基地质简图(李永军等,2007a)

P_2x-中二叠统晓山萨依组;C_1a-下石炭统阿克沙克组;C_1d-下石炭统大哈拉军山组;1-正长花岗岩;2-二长花岗岩;3-花岗闪长岩;4-花岗闪长斑岩;5-石英闪长玢岩;6-超动;7-脉动;8-角度不整合;9-断层;10-钼矿点;11-钼异常等值线;12-同位素年龄及分析方法

Fig. 2 Geological sketch map of Tekesidaban granitic batholith in Western Tianshan (after Li *et al.*, 2007a)

P_2x-Xiaoshanshayi Fm. (P_2); C_1a-Akesake Fm. (C_1); C_1d-Dahalajunshan Fm. (C_1); 1-orthoclase granite; 2-adamellite; 3-granodiorite; 4-granitic porphyry; 5-quartz dioritic porphyry; 6-beveling invading; 7-pulsation invading; 8-angular unconformity; 9-fault; 10-Mo ore spot; 11-Contour of Mo anamoly; 12-isotopic age and analytic method

长斑岩组成。石英闪长玢岩为灰白色—灰色,斑状结构,基质微细粒花岗结构,块状构造,主要由中长石、石英、角闪石组成;斑晶约占15%,由自形和半自形板状中长石组成。花岗闪长斑岩肉红色,斑状结构,基质微细粒花岗结构,块状构造。主要由板状、粒状更-中长石、钾长石、他形石英及角闪石组成。斑晶为自形和半自形板状更-中长石,含量15%~25%。埃达克岩时代为347±3Ma(李永军等,2007b)。库勒萨依序列9个样品分析数据及相关参数见表1。由表中可知,SiO_2含量57.06%~70.74%,均>56%。具有高Al_2O_3(15.01%~19.31%)、高Na_2O(3.58%~5.3%)且$Na_2O/K_2O>1$,低MgO(0.91%~2.73%)等特征。除个别样$\delta>4$,总体<4,平均值为3.05,属于钙碱性系列,这与SiO_2-Na_2O+K_2O图解结论一致(图3),这些岩石化学含量与参数均与典型埃达克岩特征吻合(Defant and Drummond,1990)。

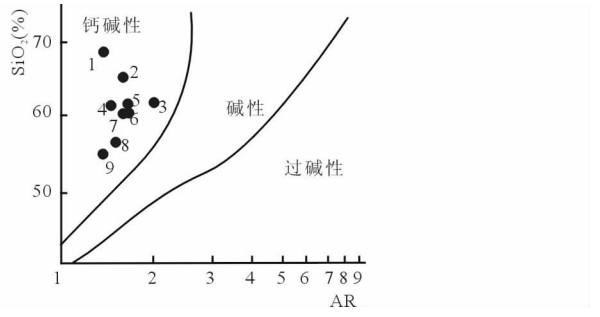


图 3 特克斯达坂岩基SiO_2-碱度图解(据Wright,1969)

Fig. 3 SiO_2-alkali diagram of Tekesidaban granitic batholith (after Wright, 1969)

库勒萨依序列埃达克岩相对亏损Nb、Ta、Zr、Hf等高场强元素(HFSE),且含量极为相似(图略),配分曲线与Pearce的岛弧钙碱性花岗岩基本一致(Pearce *et al.*,1984),但与其显著的差异是高Sr(441×10^{-6}~794×10^{-6},平均563.56×10^{-6}),低Y(4.73×10^{-6}~14.9×10^{-6},平均11.06×10^{-6},故Sr/Y值>40×10^{-6},平均57.67)、Yb(0.7×10^{-6}~1.88×10^{-6},平均1.33×10^{-6}<1.9×10^{-6})和强烈亏损HREE等。在Sr/Y-Y图(图4a)、Nd/Sr-La/Nb图(图4b)等判别图解中,均无例外的落入埃达克岩区。

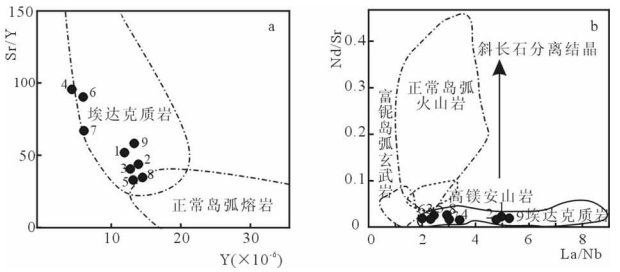


图 4 库勒萨依序列埃达克岩Sr/Y-Y图和Nd/Sr-La/Nb图

(a-底图据Drummond and Defant,1990;b-底图据赵振华等,2004)

Fig. 4 Sr/Y-Y(a, after Drummond and Defant,1990) and Nd/Sr-La/Nb (b after Zhao *et al.*, 2004) diagram of Kulesayi series adakite

稀土总量总体较低,但有明显相对高LREE和亏损HREE特征,$(La/Yb)_N$平均为4.64,表明LREE元素略有富

表 1 库勒萨依序列埃达克岩岩石地球化学数据

Table 1 The representative composition of Kulesayi series adakites

	1	2	3	4	5	6	7	8	9	平均值
SiO_2	70.74	67.37	63.94	63.71	63.69	62.70	62.58	58.48	57.06	63.36
TiO_2	0.42	0.51	0.72	0.85	0.58	0.93	0.92	0.90	0.93	0.75
Al_2O_3	15.01	15.40	15.52	15.60	16.27	16.07	16.94	17.02	19.31	16.35
Fe_2O_3	1.03	1.59	1.75	2.16	1.65	2.24	2.32	3.17	2.59	2.06
FeO	2.03	2.97	3.96	3.39	3.52	3.49	3.53	3.85	5.41	3.57
MnO	0.08	0.08	0.10	0.09	0.13	0.11	0.10	0.12	0.12	0.10
MgO	0.91	1.22	1.70	1.70	2.67	1.63	2.21	2.73	2.54	1.92
CaO	1.83	1.31	3.37	3.22	2.55	3.22	1.70	2.28	5.83	2.81
Na_2O	4.56	4.32	3.58	3.88	4.49	4.06	5.10	5.30	4.24	4.39
K_2O	3.26	3.77	3.87	3.76	2.37	4.13	4.30	4.03	1.85	3.48
P_2O_5	0.14	0.15	0.22	0.25	0.12	0.25	0.30	0.38	0.29	0.23
总量	100.01	98.69	98.73	98.61	98.04	98.83	100.00	98.26	100.17	99.04
Fe_2O_3/MgO	1.13	1.30	1.03	1.27	0.62	1.37	1.05	1.16	1.02	1.07
里特曼指数 δ	2.20	2.69	2.65	2.82	2.27	3.40	4.51	5.62	2.64	3.05
Ba	804	188	209	74	229	101	88	353	540	287
Rb	87.60	26.00	16.50	3.15	6.40	9.10	18.60	14.30	68.80	27.83
Sr	643	626	543	454	452	593	441	526	794	563
Y	12.30	14.20	13.30	4.73	13.50	6.48	6.56	14.90	13.60	11.06
Zr	146	65.70	69.20	43.10	62.90	58.60	72.10	82.00	126	80.62
Nb	2.69	2.21	2.22	1.52	3.57	1.97	1.51	4.75	3.14	2.62
Th	6.22	18.30	22.20	19.30	15.40	20.30	64.70	14.60	11.60	21.40
Ga	27.00	17.60	15.70	10.50	15.10	14.60	13.40	12.60	23.40	16.66
Ni	14.80	111	68.60	130	12.80	69.60	83.80	5.50	82.20	64.26
Cr	78.00	65.00	107	112	24.40	10.60	218	2.40	160	86.38
Hf	3.63	1.79	2.60	1.20	2.03	1.81	1.86	2.06	4.06	2.34
Sc	13.60	27.40	44.80	10.80	36.00	9.39	21.40	31.60	14.00	23.22
Ta	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Co	13.60	25.90	21.80	36.80	24.90	20.30	27.80	24.40	1.90	21.93
Li	20.10	21.10	10.90	4.20	52.10	9.30	16.80	38.00	13.10	20.62
Be	2.50	1.00	1.06	0.40	1.18	0.69	0.67	1.31	1.34	1.13
Sn	4.50	3.55	2.40	1.90	6.00	2.30	2.70	3.40	2.75	3.28
La	13.40	10.60	5.23	5.17	8.71	3.99	4.53	14.10	16.60	9.15
Ce	26.80	18.00	10.00	8.50	15.50	7.38	7.99	23.60	31.00	16.53
Pr	3.40	2.18	1.43	0.52	2.47	0.74	0.73	3.04	3.46	2.00
Nd	16.30	9.90	7.49	3.49	11.90	5.14	4.31	15.20	15.40	9.90
Sm	3.30	2.64	1.55	0.87	2.64	1.44	1.43	3.38	3.00	2.25
Eu	0.92	1.11	0.78	0.59	0.99	0.58	0.68	1.17	0.96	0.86
Gd	3.00	3.06	2.59	1.06	2.93	1.26	1.29	3.61	3.28	2.45
Tb	0.48	0.50	0.45	0.20	0.51	0.23	0.23	0.62	0.50	0.41
Dy	2.94	3.36	3.23	1.11	3.15	1.48	1.53	3.73	3.28	2.65
Ho	0.52	0.58	0.64	0.20	0.60	0.24	0.19	0.71	0.63	0.48
Er	1.70	1.81	2.07	0.64	1.69	0.71	0.80	2.10	1.64	1.46
Tm	0.26	0.26	0.32	0.10	0.26	0.11	0.12	0.32	0.26	0.22
Yb	1.45	1.46	1.66	0.70	1.65	0.70	0.77	1.88	1.70	1.33
Lu	0.18	0.20	0.22	0.07	0.20	0.08	0.09	0.23	0.20	0.16
δEu	0.88	1.19	1.18	1.88	1.08	1.29	1.50	1.02	0.93	1.12
$(La/Yb)_N$	6.23	4.89	2.12	4.98	3.56	3.84	3.97	5.06	6.58	4.64

注:分析单位:宜昌地质研究所。氧化物用 GFAAS 原子吸收光谱法分析(wt%),稀土及微量元素用 ICPMS 分析($\times 10^{-6}$)

集。δEu 平均值大于 1(最高达 1.88),总体显示弱正 Eu 异常。配分曲线呈较陡倾斜特征(图略),与西天山阿吾拉勒埃达克质岩的配分型式(熊小林等,2001)相似,并与同时期的大哈拉军山组钙碱性火山岩配套(李注苍等,2006;朱永峰等,2005,2006a,b),共同组成早石炭世岛弧岩浆组合。

4 含矿性问题

库勒萨依序列基岩光谱的 Mo、As、Ag、Cu、W 等元素含量明显高于围岩和二叠纪其那尔萨依序列深成花岗岩(表 3)。土壤地化剖面中 Mo、Cu 等元素强烈富集,浓集中心明显,浓度分带清晰,有 5 个样品 Mo 元素含量大于 0.15%,最高值达到 0.261%,已高于工业品位。说明 Mo 矿化与 Adakite 有密切关系。在 SiO_2-Yb 成矿埃达克岩图解上,三个采自 Mo 异常之东侵入体的样品(4、6、7 号)落入非成矿埃达克岩区,而其余样品均落入成矿埃达克岩区(图 5),证实了 Mo 成矿与埃达克岩密切相关。槽探揭露发现钼矿体 1 个,矿化体 2 条。控制长度 350m,宽 1.5m~2.9m,平均 2.2m;钼含量 0.041%~0.3%,平均 0.15%。库勒萨依沟口仅有的 5 钻工程证实,矿体向深部厚度明显变厚,已控制矿体 4 条,长度大于 500m,D 级储量有望达到中型,而其找矿靶区大部分地段还未进行工程控制,因而找矿前景良好。

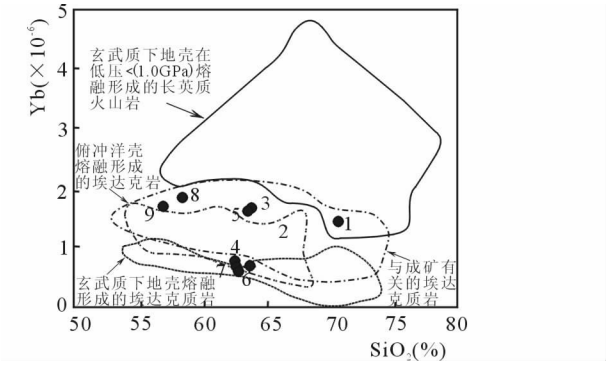


图 5 库勒萨依序列埃达克岩 SiO_2-Yb 图(底图据赵振华等,2004)

Fig. 5 SiO_2-Yb diagram of Kulesayi series adakite (after Zhao *et al.*, 2004)

表 3 库勒萨依序列埃达克岩的基岩光谱数据平均值对比表

Table 3 Contrast table of the average data for bedrock spectrum of Kulesayi series adakite

序列 \ 分析项目	As	Sb	Pb	Ag	Cu	Zn	Mo	W	Au
库勒萨依序列(14 样)	5.93	0.34	15.64	5.35	49.02	54.51	8.31	12.91	0.71
其那尔萨依(42 样)	1.55	0.13	12.56	0.03	18.56	58.94	0.85	1.73	0.86

样品由新疆地质矿产局实验测试中心用原子吸收 MS 及 ICPMS 方法分析。Au 为 $\times 10^{-9}$,其余为 $\times 10^{-6}$

5 讨论与结论

埃达克岩多数产于岛弧环境并与弧火山岩伴生的重要事实使人相信,埃达克岩是俯冲到一定深度的洋壳板片发生部分熔融的产物(Thieblemont *et al.*, 1997; Defant and Kepezhinskas, 2001)。埃达克质岩之所以与 Cu-Mo-Au 矿床密切相关,是以其高水含量、高氧逸度(f_{O_2})和富硫为特征(Oyarzun *et al.*, 2001),因而成为斑岩铜钼矿的重要含矿母岩和金属硫的可能载体。富水的俯冲洋壳板片部分熔融,可以形成富水的、具英安质成分特征的埃达克质熔体。同时,氧逸度的提高还引起岩浆系统中 SO_2/H_2S 比值急剧增大,从而导致 S 从埃达克质熔体中完全分离(Burnham, 1979)。初生的埃达克质熔体与地幔橄榄岩/幔源熔体的相互作用,是埃达克质熔体获取金属和硫的重要途径。在弧造山环境,起源于俯冲洋壳板片的埃达克质熔体在向上运移过程中,势必与上覆的地幔橄榄岩发生相互反应,这将大幅度提高埃达克质熔体的 $Mg^{\#}$ 值和 Fe、Cr、Ni 含量(Keleman, 1995),从而增大硫在熔体中的溶解度。同时提高了幔岩的 f_{O_2},导致幔岩中的金属氧化并进入岩浆系统,为埃达克质熔体提供大量的钼等金属以及硫(侯增谦等,2003)。

库勒萨依序列斑岩体属于钙碱性系列岛弧浅成岩,高 Al_2O_3、Na_2O、Sr 和 LREE,低 MgO、Y、Yb 且强烈亏损 HREE(具有正 Eu 异常),$Na_2O/K_2O>1$,Sr/Y 平均 57.67,具有 O 型埃达克岩的地球化学特征。该埃达克岩与区内的 Mo 异常有较好的套合性,Mo、As、Ag、Cu、W 等元素含量明显高于围岩和二叠纪其那尔萨依序列深成花岗岩,已控制工业矿体,找矿前景良好。

晚古生代天山地区完成了从大洋向大陆的转化,与这一洋陆转化过程相伴的是天山地区十分醒目的高峰期岩浆活动和大规模成矿事件。特克斯达坂库勒萨依序列埃达克岩是南天山洋在早石炭纪末期向北俯冲并发生了板片的部分深熔作用而形成的,板片的俯冲,是导致含矿埃达克岩浆形成发育的主导性动力学机制(侯增谦,2004)。俯冲中洋壳板片开始部分融熔。融熔岩浆在上侵过程中与富含 Cu、Au、Mo 等金属元素的地幔和下地壳的基性岩产生交换作用,使库勒萨依序列 adakite 质岩浆中 Cu、Au、Mo 等金属元素丰度增高并在有利条件下富集成矿。

新解体的库勒萨依浅成岩序列与本区的早石炭世大哈拉军山组钙碱性火山岩共同构成了岛弧火成岩组合(姜常义等,1993,1995;李注苍等,2006;Zhu *et al.*, 2006, 2007; 朱永峰等,2006a,b),而其那尔萨依深成岩序列与晚石炭世—早二叠世大陆裂谷环境双峰式火山岩共同构成了板内裂谷火成岩组合(姜常义等,1993,1995;刘静等,2006)。特克斯达坂岩基的解体,不仅客观反应了区内地质体的分布特征与规律,而且为区内寻找斑岩型铜、钼矿床提供了新的找矿思路和理论依据。

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