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东昆仑夏日哈木岩浆铜镍硫化物矿床成矿时代的厘定及其找矿意义

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提要:青海省夏日哈木岩浆硫化物矿床是近两年于东昆仑造山带新发现的超大型镍矿床,其赋矿岩性与形成时的地球动力学机制和构造环境认识是制约找矿更大突破的关键控制因素。本文拟通过成岩成矿时代的确定来探讨其形成时的构造背景,进而指出东昆仑地区该类矿床的找矿意义和潜力。野外钻孔岩心详细编录,发现岩浆硫化物绝大多数都富集于橄榄岩相、辉石岩相等的超镁铁质岩类,与矿化较弱的辉长岩非同期的产物。对采集到的矿体顶底板无矿化的橄辉岩钻孔岩心样品挑选锆石进行U−Pb年代学测定,获得了(412.9±1.8)Ma(MSWD=1.2)和(410.9±1.6)Ma(MSWD=3.1)的谐和年龄。同样方法获得的辉长岩的年龄则老20 Ma,进一步说明含矿超镁铁质岩与无矿辉长岩非同期产物。系统的橄榄石成分及*Fo*值研究,初步揭示了岛弧岩浆特点的信息。综合区域内榴辉岩的厘定及年龄测试,初步认为夏日哈木超大型岩浆铜镍硫化物矿床岩浆源区表现了东昆仑弧的特点,随着部分熔融发生的岩浆上涌,深部和浅部均产生了硫化物的不混溶作用,分异的岩浆于柴达木克拉通南缘东昆仑造山带碰撞后的构造薄弱部位成岩成矿,地壳浅部围岩S的混入对镍矿体的形成具有重要贡献。这一认识对于东昆仑其他镁铁−超镁铁质侵入岩体的含矿性评价和拓展区域找矿潜力具有重要的找矿指示意义和研究价值。

关 键 词:镁铁−超镁铁质岩体;地质特征;成矿时代;找矿意义;东昆仑
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Metallogenic epoch of the Xiarihamu magmatic Ni−Cu sulfide deposit in eastern Kunlun orogenic belt and its prospecting significance

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Abstract: The superlarge Xiarihamu magmatic Ni−Cu sulfide deposit is located in eastern Kunlun orogenic belt of Qinghai Province. The study of its mineralization, lithology, geodynamic mechanism and tectonic setting is very important for further prospecting breakthrough in eastern Kunlun orogenic belt. This paper discusses the tectonic setting of the mineralization in Xiarihamu magmatic Ni−Cu deposit through the dating of Xiarihamu mafic−ultramafic intrusion, and further indicates the prospecting significance and potentiality of eastern Kunlun region. Most magmatic sulfides were found in peridotites and pyroxenites through drilling, and the Ni−bearing ultramafic intrusion orebody is different from the gabbro in the formation time. The zircon U−Pb ages of barren olivine−pyroxenite from Xiarihamu ultramafic intrusion drilling core are 412.9±1.8 Ma (MSWD=1.2) and 410.9±1.6 Ma (MSWD=3.1), about 20 Ma younger than the age of gabbro. It is revealed that parent magma had the island arc magma characteristics, as shown by systematic olivine composition and Fo value study of Xiarihamu ultramafic intrusion drilling core samples. Based on these data, together with the age of eclogite in this region, the authors preliminarily hold that the magma source of Xiarihamu ultramafic intrusion had the characteristics of eastern Kunlun island arc. There occurred sulfide immiscibility of silicate magma with the upwelling of the partial melting magma, and the differentiated magma intruded into the structurally weak location of post collision in eastern Kunlun orogenic belt and formed the superlarge Xiarihamu magmatic Ni−Cu deposit. The crustal contamination of S played a very important role in forming the Ni orebody. This understanding is of great prospecting significance and research value for mineralization evaluation and potentiality exploration around other mafic−ultramafic intrusions in eastern Kunlun orogenic belt.

Key words: mafic−ultramafic intrusion; geological characteristics; metallogenic epoch; prospecting significance; eastern Kunlun orogenic belt

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1　引　言

自19世纪岩浆铜镍硫化物矿床被发现以来，经过了150多年的研究和发展，在成矿理论、形成机制、产出背景、发育时代等方面取得了较为系统的认识和大量的研究成果[1−2]。如岩浆铜镍硫化物矿床多产于板内或大的地块边缘，中生代以老的地质时代都可以发育，主要是硫化物不混溶的结果，等等[3−11]。但对于造山带背景中发育的铜镍矿床研究较少，此环境能否形成超大型规模的镍矿床认识不清，其形成机制与成矿过程如何？这些都是至今在造山带岩浆铜镍硫化物矿床方面研究不太清楚的问题。青海省夏日哈木岩浆铜镍硫化物矿床是近两年于东昆仑造山带地区化探异常检查时被发现的[12]。经普查、详查及勘探大量的深部钻探工作，已控制镍金属量110万t，达超大型矿床规模。截至目前，在国内是仅次于甘肃省金川岩浆铜镍（铂族）硫化物矿床的第二大镍矿床。夏日哈木岩浆铜镍硫化物矿床的主要发现者和勘探者论述了其地质背景、含矿岩体及矿床地质特征，并提出了对矿床成因的认识。获得了夏日哈木Hs26号异常所对应岩体辉长岩的锆石U−Pb年龄为（393.5±3.4）Ma，阐述了形成夏日哈木镁铁质−超镁铁质岩体及所含镍矿床的地幔动力学机制，认为是消减板片断离且形成板片窗，从而诱发软流圈地幔上涌并减压熔融在相应位置成岩成矿[12]。

详细的野外调查和钻孔岩心编录，发现夏日哈木岩浆铜镍硫化物矿床的含矿岩体是由橄榄岩相、辉石岩相及少量辉长岩相的多期次岩浆活动的结果。镍矿体的形成只与橄榄岩相及辉石岩相有关，辉长岩相在含矿的超镁铁质岩相之前之后均有发育，初步显示辉长岩相与镍成矿期没有关系。可见，夏日哈木岩浆铜镍硫化物矿床及其含矿岩体的地质特征有待进一步鉴别，其硫化物熔离机制与成矿过程、岩浆源区性质及可能的构造背景也是制约深部找矿及含矿岩体形成过程的关键因素。本研究拟从夏日哈木镁铁−超镁铁质岩体的空间形态和岩相分异入手，有效确定该岩体的形成时代和硫化

物不混溶制约因素，探讨可能产出的构造地质背景和成矿环境，对于深化造山带构造背景岩浆铜镍硫化物矿床的形成机理认识、指导区域内类似岩体及矿床的发现与勘查，具有重要指示作用和研究意义。

2　区域地质构造背景

东昆仑造山带整体位于青藏高原的东北部，北邻塔里木、华北陆块群，处于古特提斯洋盆北部大陆边缘，地质构造演化和成矿作用是特提斯洋与古陆块群相互作用的结果[13]。东昆仑整体区域构造演化先后经历5个阶段：太古宙—古元古代古陆核形成阶段、中新元古代古大陆裂解与超大陆汇聚阶段、南华纪—早古生代洋陆转换阶段、晚古生代—早古生代洋陆转换阶段以及中新生代陆内造山阶段。东昆仑造山带依据区域性大断裂划分了几个大的次级构造单元，昆北断裂带、黑山—那陵格勒断裂、昆中断裂带以及昆南断裂带将东昆仑自北而南分为祁漫塔格早古生代岩浆弧、中昆仑微陆块以及昆南增生楔杂岩带3个部分[13-18]。昆仑造山带以阿尔金断裂为界分为西昆仑造山带和东昆仑造山带，东昆仑造山带延伸近500 km，东部与秦岭造山带接触，北面是柴达木克拉通和祁连微陆块，它们之间缝合带的榴辉岩年龄为441~457 Ma[19-20]。而祁连陆块与阿拉善陆块之间缝合带榴辉岩的年龄约为464 Ma[19]，略微老于祁连地块与柴达木克拉通之间缝合带榴辉岩的年龄(图1-a)。东昆仑造山带以昆中区域性大断裂又可进一步分为昆北和昆南造山带，大量391~410 Ma的花岗岩发育于昆北造山带中。这些花岗岩侵入到前寒武纪变质基底及古生代火山沉积地层中，零星可见三叠纪沉积地层。在昆北造山带的东部，发现有榴辉岩(约428 Ma)[21]。其他几处蛇绿混杂岩的年龄变化在467~518 Ma，并且这些蛇绿混杂岩的玄武质岩石表现出了典型的MORB特征[22-24]。由此推测，昆北造山带地体大约于428 Ma拼贴到柴达木克拉通的南部边缘。

祁漫塔格早古生代岩浆弧以昆北断裂带为界与柴达木盆地接壤，昆南增生楔杂岩带则以昆南断裂带为界与巴颜喀拉造山带毗邻。青海省夏日哈木超大型岩浆铜镍硫化物矿床就产出于祁漫塔格早古生代岩浆弧内，临近黑山—那陵格勒断裂(图1-c)。矿区出露地层主要为古元古代白沙河岩群，岩石类型为黑云斜长片麻岩、眼球状混合片麻岩、大理岩、二云石英片岩等，原岩恢复为碎屑岩-碳酸盐岩-火山岩建造，经历了角闪岩相区域变质作用。几个不同时代不同规模的岩浆铜镍硫化物矿床发育于东昆仑造山带的北部，如牛鼻子梁(柴达木西北缘402 Ma)(另文发表)、亚曲(东南祁连441 Ma)[7]、裕龙沟(东南祁连443 Ma)[7]，金川(华北克拉通西南缘831 Ma)[25]。但牛鼻子梁、亚曲及裕龙沟等由于岩体规模太小并未发现具有较大经济价值的矿体。金川矿床自20世纪70年代开发利用以来，迄今为止也是世界上单个矿床规模最大的岩浆铜镍硫化物矿床(图1-b)。

3　岩体地质及岩相学特征

夏日哈木岩浆铜镍硫化物矿床所在区域目前已发现5个镁铁-超镁铁质岩体，分别对应化探异常查证时的Hs25号异常、Hs26号异常、Hs27号异常、Hs28号异常及Hs31号异常，对应的岩体编号分别为Ⅲ号、Ⅰ号、Ⅱ号和Ⅳ号(图2)。夏日哈木铜镍矿体基本都产在Hs26号异常所对应的岩体，因而将其名为Ⅰ号岩体，本文所研究及讨论的也都是Ⅰ号岩体(图3)。矿区北部的正长花岗岩基形成于(391.1±1.4)Ma[26]。断裂构造以近东西向和北西西向为主，形成时代早。北东向和南北向断裂规模相对较小，形成时代晚，经常错断近东西向和北西西向断层(图2)。

夏日哈木矿区Ⅰ号岩体据钻孔施工及勘探工作，初步确定其岩体形态，长约1.5 km，宽约0.8 km，长轴方向近东西向，西段略向南偏转(图3-a)，岩体顶界面东高西低，东段出露于地表，西段隐伏于地下，且越向西埋深越深(图3-a、e)，总体形态为向西倾伏的岩床(图3)。夏日哈木矿区Ⅰ号岩体在地表有氧化蚀变带及铁帽出露，主要集中在0号勘探线东西两侧，1号勘探线与4号勘探线之间的区域(图3-a)。从3条勘探线(2号、9号和17号勘探线)钻孔纵剖面图(图3-b、c、d)来看，岩体岩性主要是辉石岩相、橄榄岩相、辉长岩相及少量的花岗岩脉(图4-a、b)，并且橄榄岩相越向西橄榄石含量逐渐增多，同时埋深加大，围岩地层厚度增厚。上述情况在钻孔横剖面图上则更加明显直观(图3-e)，沿着NM线248°方向，岩石基性程度变深、岩体埋深增大、橄榄石含量增多、矿体增厚变富。

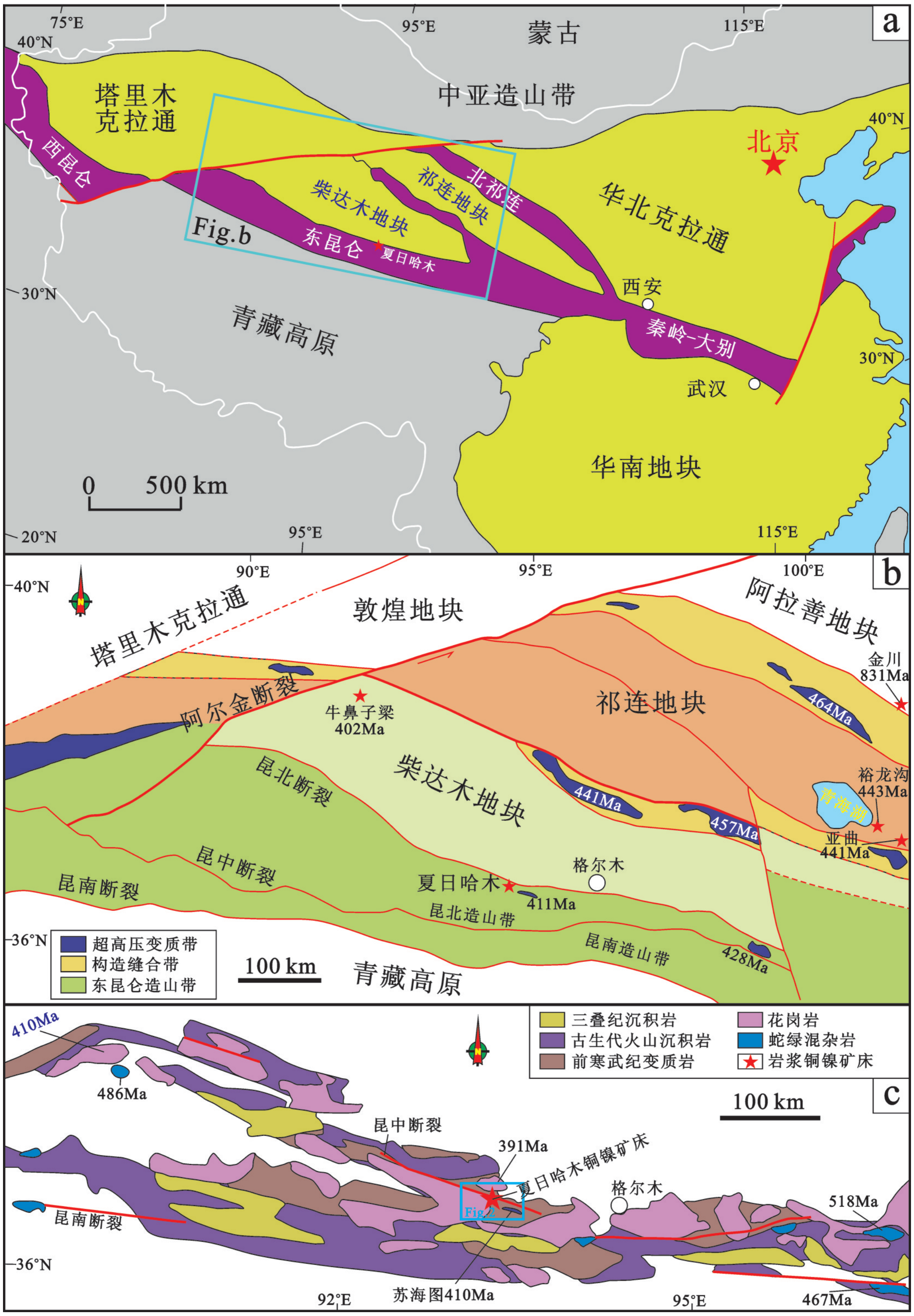

图1 东昆仑夏日哈木铜镍矿区域构造及地质略图

Fig.1 Schematic tectonic and geological map of the Xiarihamu Cu−Ni deposit in eastern Kunlun orogenic belt

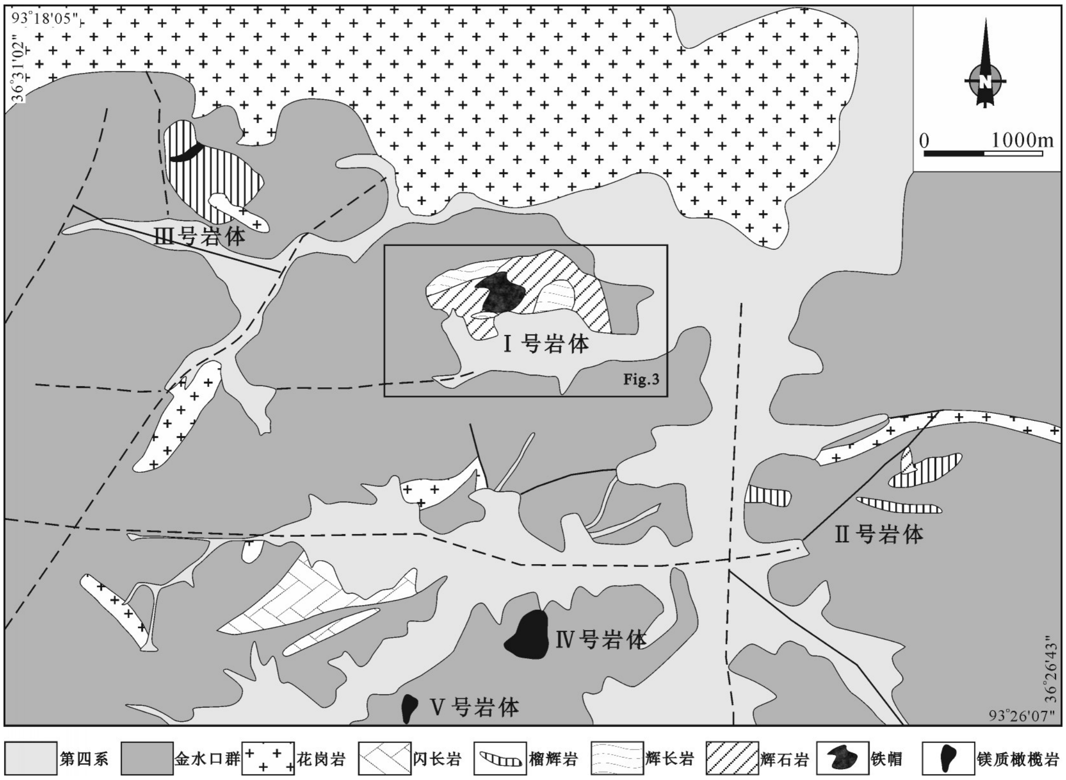

图2 东昆仑夏日哈木岩浆铜镍硫化物矿区岩体地质分布略图
Fig.2 Schematic geological map for mafic−ultramafic intrusions from the Xiarihamu magmatic Ni−Cu deposit in eastern Kunlun orogenic belt

夏日哈木矿区镍矿体主要赋存于辉石岩相与橄榄岩相中，基本不含矿的辉长岩相与含矿的辉石岩相及橄榄岩相明显不是同期的产物。镍矿体只要赋存于夏日哈木矿区Ⅰ号岩体2号(AB线)勘探线以西地表以下的区域，在9号勘探线、11号勘探线的位置区域，镍矿体达到了最厚(超过300 m)，随着勘探线号的变大(向西)，岩体变薄、埋深增厚、橄榄石增多、镍矿体变富(图3−b、c、d、e)。矿石矿物主要是镍黄铁矿、磁黄铁矿及少量的黄铜矿(图4−e、f)，结构构造中可见明显的橄榄石被辉石包裹的典型包橄结构(图4−c、d)。

4 分析方法

锆石单矿物分选工作在河北省区域地质矿产调查研究所实验室完成。锆石CL图像在西北大学大陆动力学国家重点实验室电子探针仪加载的阴极发光仪上完成。锆石LA− ICP−MS U−Pb定年测试分析在中国地质科学院矿产资源研究所国土资源部成矿作用与资源评价重点实验室完成，定年分析仪器为Finnigan Neptune型ICP−MS及与之配套的Newwave UP 213激光剥蚀系统。激光剥蚀束斑直径为40 μm，以He为载气。对锆石标准的定年精度和准确度在1%(2s)左右，锆石U−Pb定年以锆石GJ−1为外标，U、Th含量以锆石M127(U: 923×10^{-6}; Th: 439×10^{-6}; Th/U: 0.475)为外标进行校正[27]。数据处理采用ICP MS DataCal程序[28]，锆石年龄及谐和图绘制用Isoplot 3.0程序。详细分析步骤和数据处理方法见侯可军等[29]。

5 分析结果

采集夏日哈木岩浆铜镍硫化物矿床矿体上下盘不含矿的钻孔岩心进行锆石挑选，具体位置是钻孔ZK5E07S340−350 m处和钻孔ZK1501S330−340 m处的岩心，岩性为非矿化橄辉岩。所选锆石形态如CL图像(图5)所示，普遍发育振荡环带，具有岩浆成因锆石的普遍特征。对41颗锆石进行U−Pb含量分析(表1、表2)，其比值年龄集中在401~420 Ma，相对比较集中，获得(412.9±1.8)Ma(MSWD=

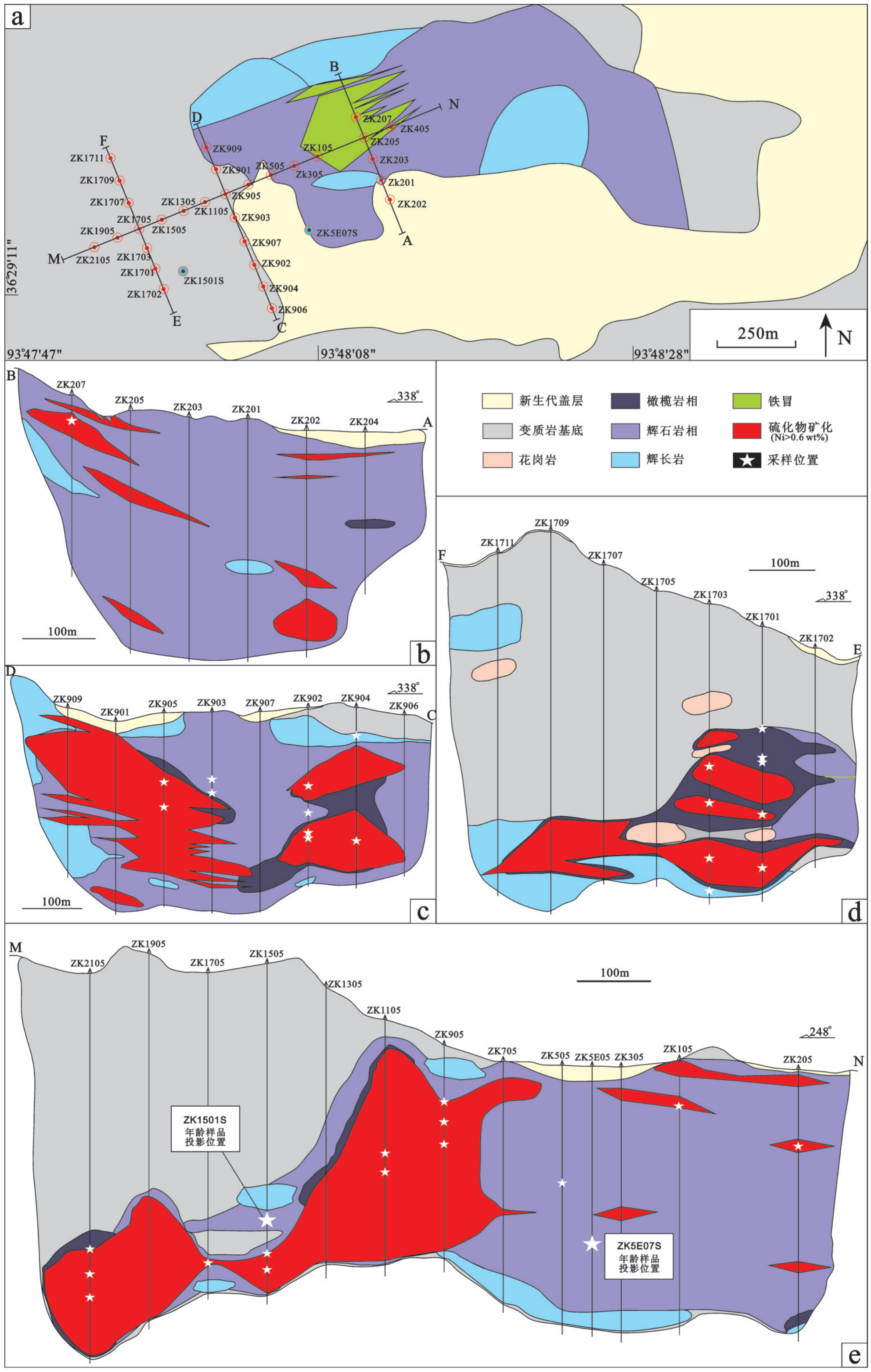

图3 东昆仑夏日哈木矿区Ⅰ号岩体平面(a)及剖面(b、c、d、e)地质略图

Fig.3 Schematic geological plan view (a) and profiles (b, c, d, e) of Xiarihamu intrusion Ⅰ in eastern Kunlun orogenic belt

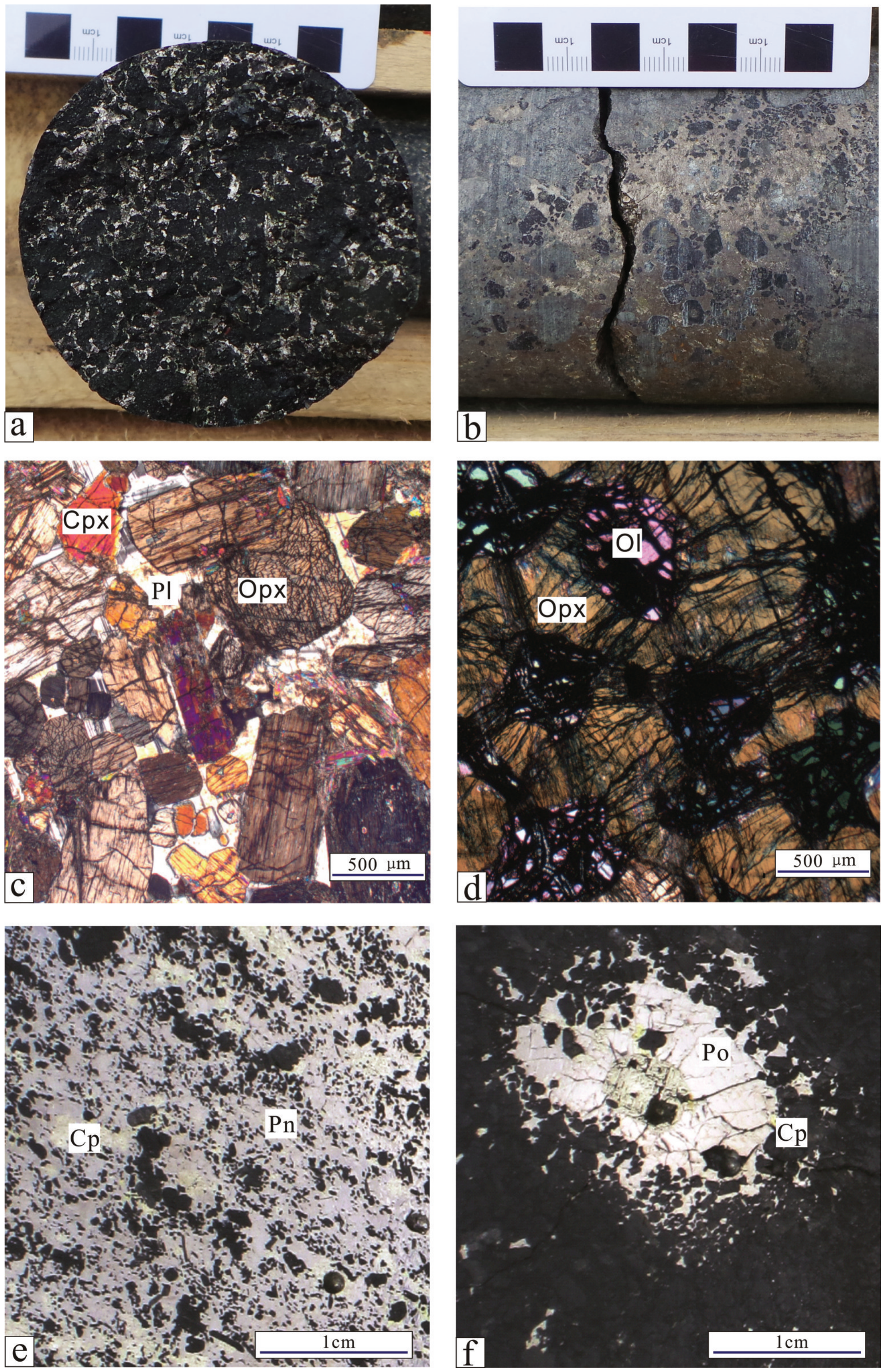

图4 夏日哈木矿区岩矿石显微照片

Cp—黄铜矿;Pl—斜长石;Po—磁黄铁矿;Pn—镍黄铁矿;Ol—橄榄石;Cpx—单斜辉石;Opx—斜方辉石

Fig.4 Microphotographs of rocks and ore minerals in the Xiarihamu magmatic Ni−Cu sulfide deposit

Cp−Chalcopyrite;Pl− Plagioclase; Po− Pyrrhotite; Pn− Pentlandite;Ol−Olivine;Cpx−Clinopyroxene;Opx− Enstenite;

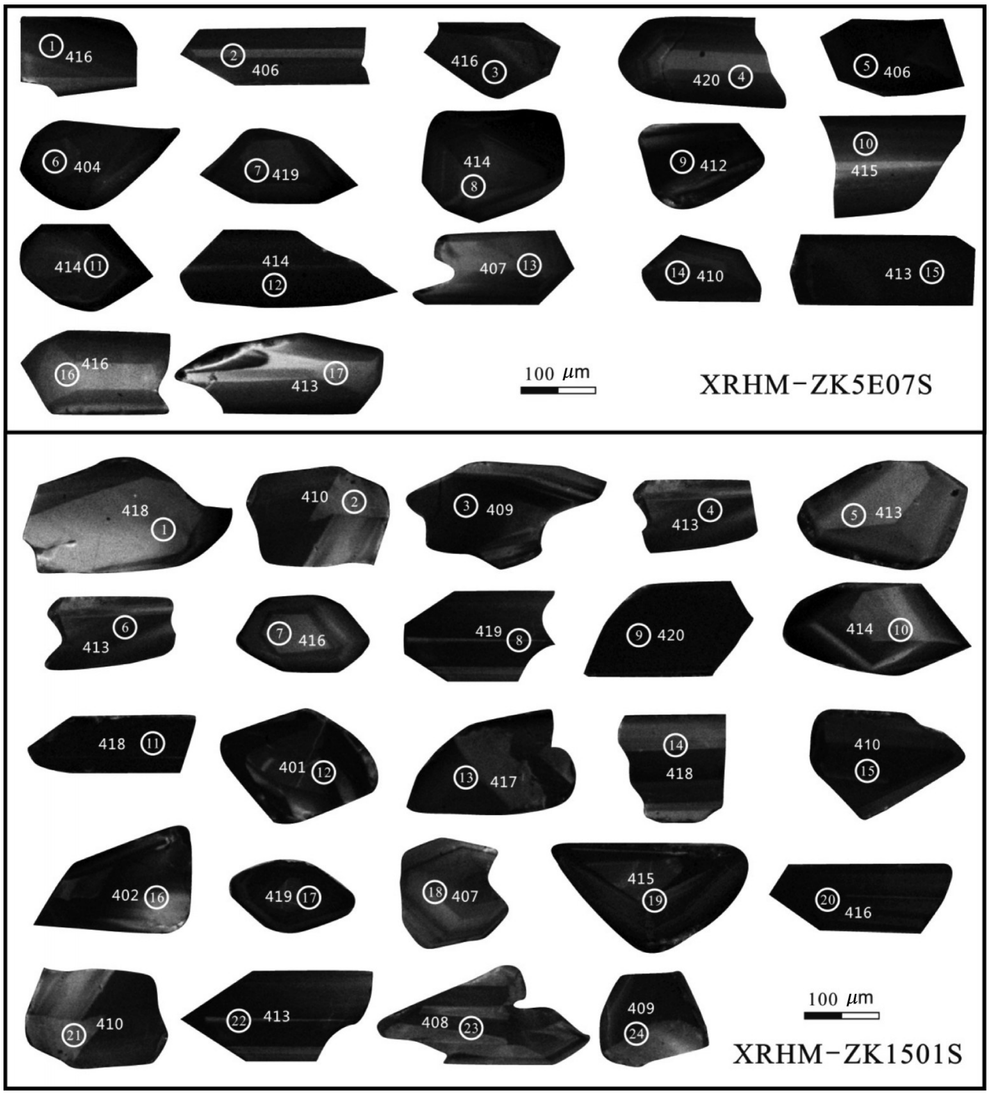

图5 东昆仑夏日哈木岩浆铜镍硫化物矿床锆石CL图像
(圆圈内的数字为测点，其外的数值为年龄，单位Ma)
Fig.5 CL images of the Xiarihamu magmatic Ni−Cu sulfide deposit in eastern Kunlun orogenic belt

1.2）和（410.9±1.6）Ma（MSWD=3.1）的谐和年龄，比较一致的年龄信息可代表夏日哈木岩浆铜镍硫化物矿床含矿岩性的形成时代。将2组数据集中处理获得（411.6±2.4）Ma（MSWD=0.33）的谐和年龄数值，即东昆仑夏日哈木岩浆铜镍硫化物矿床成岩成矿时代确定为（411.6±2.4）Ma（MSWD=0.33），属于泥盆纪早期。

6 讨论与结论

6.1 形成背景探讨

镁铁−超镁铁质侵入岩及其所含岩浆铜镍硫化物矿床的构造背景认识具有重要意义[30−32]。这也是岩浆矿床的主要特点，镍矿体基本全都赋存在镁铁−超镁铁质侵入岩体的中下部，位置相对固定。该类矿床一般形成于稳定克拉通边缘，是裂谷环境的产物，地幔柱活动或者大火成岩省也能形成岩浆铜镍硫化物矿床，在中国造山带背景碰撞后拉伸环境也产生了多个镍矿床，迄今为止，只是在矿床规模上没有超大型的发现[33−36]。青海省东昆仑夏日哈木超大型岩浆铜镍硫化物矿床的发现，改变了这一认识，110万t Ni金属集聚于青海省夏日哈木地区，是大规模岩浆活动的结果。获得赋矿橄辉岩精确的锆石U−Pb年龄为（411.6±2.4）Ma（MSWD=0.33），对应着东昆仑造山后后碰撞环境的时代特

表1 东昆仑夏日哈木岩浆铜镍硫化物矿床XRHM−ZK5E07S橄辉岩锆石U−Pb同位素年龄数据

Table 1 U−Pb isotopic data for chemically abraded zircon grains from XRHM−ZK5E07S of the Xiarihamu magmatic Ni−Cu deposit in eastern Kunlun orogenic belt

点号	样品编号	Pb	Th	U	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$ / Ma	1σ
			$/10^{-6}$										
1	XRH-b2-1	28	262	355	0.74	0.05555	0.00226	0.51008	0.02127	0.06663	0.00104	415.8	6.3
2	XRH-b2-2	36	334	455	0.73	0.05624	0.00267	0.49289	0.02262	0.06500	0.00177	406.0	10.7
3	XRH-b2-3	47	326	623	0.52	0.05501	0.00203	0.50653	0.02180	0.06661	0.00148	415.7	8.9
4	XRH-b2-4	20	175	256	0.68	0.05556	0.00291	0.51330	0.02816	0.06730	0.00167	419.9	10.1
5	XRH-b2-5	50	324	692	0.47	0.05576	0.00216	0.49681	0.01885	0.06506	0.00118	406.3	7.1
6	XRH-b2-6	32	244	437	0.56	0.05546	0.00238	0.49170	0.02052	0.06472	0.00137	404.2	8.3
7	XRH-b2-7	22	182	290	0.63	0.05573	0.00487	0.51791	0.04871	0.06717	0.00194	419.1	11.7
8	XRH-b2-8	16	119	227	0.52	0.05543	0.00252	0.50610	0.02293	0.06635	0.00112	414.2	6.8
9	XRH-b2-9	99	1142	1226	0.93	0.05639	0.00653	0.51447	0.05618	0.06599	0.00125	411.9	7.6
10	XRH-b2-10	15	155	200	0.78	0.05600	0.00328	0.51130	0.02872	0.06650	0.00102	415.0	6.1
11	XRH-b2-11	55	347	803	0.43	0.05767	0.00327	0.52998	0.03261	0.06624	0.00115	413.5	7.0
12	XRH-b2-12	126	1489	1686	0.88	0.05520	0.00188	0.50572	0.01676	0.06629	0.00094	413.8	5.7
13	XRH-b2-13	18	169	267	0.63	0.05486	0.00355	0.49638	0.03442	0.06518	0.00149	407.0	9.0
14	XRH-b2-14	19	171	279	0.61	0.05471	0.00448	0.49757	0.04040	0.06559	0.00162	409.5	9.8
15	XRH-b2-15	56	526	804	0.65	0.05753	0.00193	0.52543	0.01743	0.06620	0.00087	413.2	5.2
16	XRH-b2-17	10	99	148	0.67	0.05725	0.00460	0.51449	0.03777	0.06665	0.00127	416.0	7.7
17	XRH-b2-18	18	190	260	0.73	0.05603	0.00504	0.51336	0.04811	0.06609	0.00182	412.6	11.0

表2 东昆仑夏日哈木岩浆铜镍硫化物矿床XRHM−ZK1501S橄辉岩锆石U−Pb同位素年龄数据

Table 2 U−Pb isotopic data for chemically abraded zircon grains from XRHM−ZK1501S of the Xiarihamu magmatic Ni−Cu deposit in eastern Kunlun orogenic belt

点号	样品编号	Pb /10^{-6}	Th /10^{-6}	U /10^{-6}	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$ /Ma	1σ
1	XRH-b4-1	15	102	234	0.43	0.05572	0.00336	0.51431	0.03087	0.06703	0.00188	418.2	11.4
2	XRH-b4-2	56	572	839	0.68	0.05809	0.00500	0.53061	0.05828	0.06571	0.00488	410.2	29.5
3	XRH-b4-3	65	767	965	0.80	0.05831	0.00527	0.52925	0.04867	0.06550	0.00225	409.0	13.6
4	XRH-b4-4	16	131	253	0.52	0.05651	0.00389	0.51294	0.03612	0.06615	0.00200	412.9	12.1
5	XRH-b4-5	48	533	728	0.73	0.05807	0.00265	0.52924	0.02510	0.06612	0.00149	412.7	9.0
6	XRH-b4-6	18	144	299	0.48	0.05794	0.00698	0.52196	0.06760	0.06626	0.00711	413.6	43.0
7	XRH-b4-7	15	118	247	0.48	0.05564	0.00854	0.50678	0.07633	0.06664	0.00285	415.9	17.2
8	XRH-b4-8	51	619	790	0.78	0.06141	0.00693	0.55907	0.07087	0.06712	0.00611	418.8	36.9
9	XRH-b4-9	94	1165	1414	0.82	0.05722	0.00248	0.53039	0.02422	0.06730	0.00140	419.9	8.5
10	XRH-b4-10	22	249	371	0.67	0.05591	0.00271	0.50599	0.02413	0.06625	0.00126	413.5	7.6
11	XRH-b4-11	89	1334	1334	1.00	0.05678	0.00204	0.52307	0.01871	0.06698	0.00129	417.9	7.8
12	XRH-b4-12	28	306	471	0.65	0.05592	0.00267	0.48780	0.01944	0.06417	0.00091	400.9	5.5
13	XRH-b4-13	32	250	569	0.44	0.05612	0.00352	0.51963	0.03632	0.06682	0.00166	416.9	10.0
14	XRH-b4-14	38	551	619	0.89	0.05657	0.00340	0.52255	0.03081	0.06699	0.00159	418.0	9.6
15	XRH-b4-15	55	898	906	0.99	0.05522	0.00160	0.49963	0.01482	0.06557	0.00091	409.4	5.5
16	XRH-b4-16	42	424	785	0.54	0.05518	0.00277	0.48834	0.02357	0.06433	0.00111	401.9	6.7
17	XRH-b4-17	37	439	646	0.68	0.05760	0.00361	0.53590	0.04182	0.06713	0.00216	418.8	13.0
18	XRH-b4-18	17	148	331	0.45	0.05554	0.00211	0.50086	0.02009	0.06516	0.00083	406.9	5.0
19	XRH-b4-20	31	353	569	0.62	0.05512	0.00215	0.50467	0.01936	0.06645	0.00094	414.7	5.7
20	XRH-b4-21	71	1184	1231	0.96	0.05720	0.00347	0.52977	0.04327	0.06661	0.00174	415.7	10.5
21	XRH-b4-22	11	111	225	0.49	0.05562	0.00340	0.49963	0.03088	0.06565	0.00118	409.9	7.2
22	XRH-b4-23	47	788	871	0.90	0.05507	0.00182	0.50411	0.01695	0.06612	0.00092	412.7	5.6
23	XRH-b4-24	21	310	405	0.77	0.05433	0.00209	0.50489	0.03135	0.06537	0.00123	408.2	7.5
24	XRH-b4-25	32	395	655	0.60	0.05423	0.00214	0.49189	0.01811	0.06551	0.00076	409.0	4.6

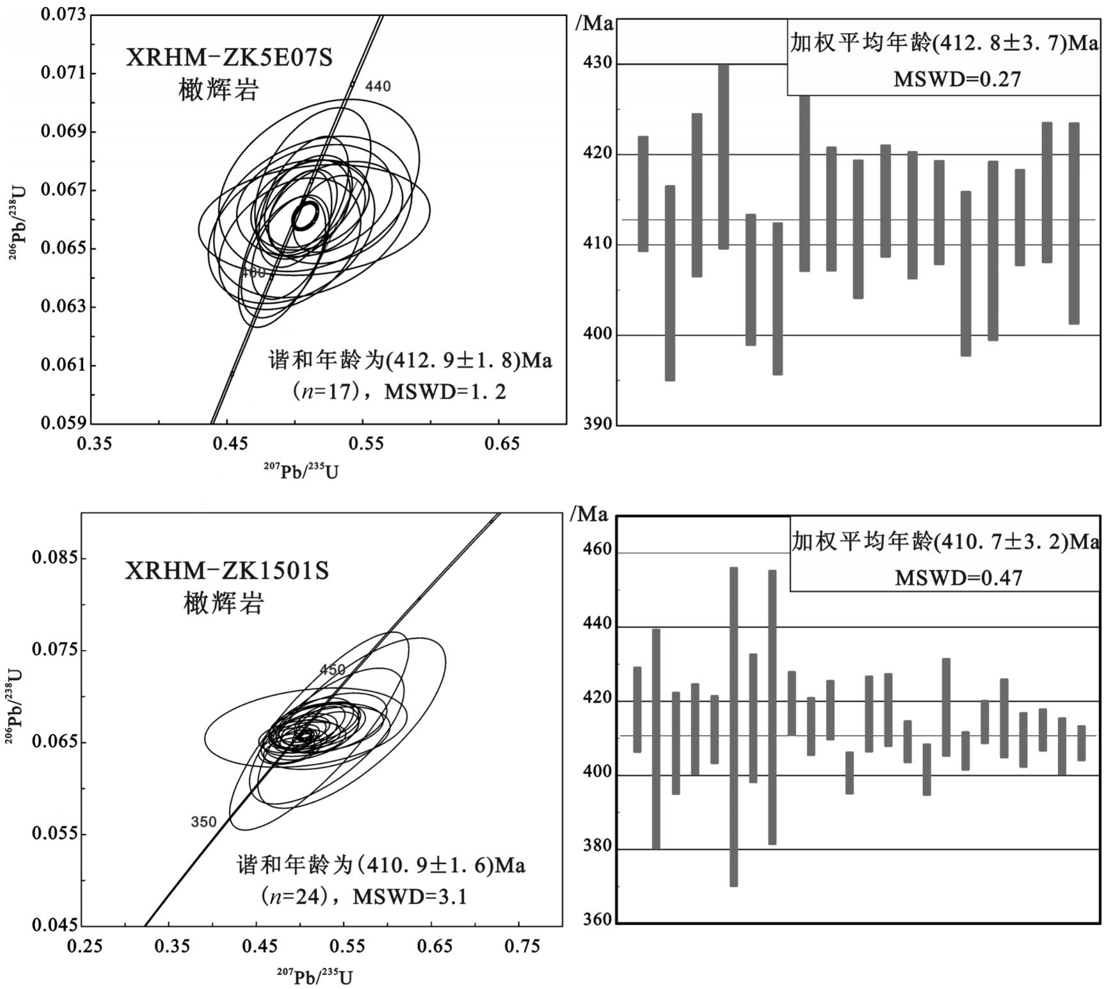

图6 东昆仑夏日哈木岩浆铜镍硫化物矿床辉橄岩锆石谐和年龄图

Fig. 6 Concordia diagrams of zircon from the Xiarihamu magmatic Ni−Cu sulfide deposit in eastern Kunlun orogenic belt

征。宋谢炎等获得了夏日哈木岩浆铜镍硫化物矿床410 Ma锆石SHRIMP年龄[37],进一步表明青海省东昆仑夏日哈木铜镍矿床形成于早泥盆世。

夏日哈木超镁铁岩母岩浆表现了富集轻REE、明显的负Nb异常,橄榄石中Ca亏损和高的SiO_2含量,表现出了弧岩浆岩的特点[38]。混有弧岩浆物质的原生岩浆,在上升过程中遭受地壳硫的混染,导致岩浆中的硫化物达到饱和,上升的岩浆中充满了不混溶的硫化物小液滴。岩浆继续向上到达夏日哈木构造薄弱部位,不混溶的硫化物液滴和一些橄榄石晶体沉淀下来形成硫化物−橄榄石的堆晶,同时岩浆继续上升到较高空间。该过程持续多次从而形成了多个硫化物聚集区,蚀变主要出现在富硫化物和贫硫化物的区域。

综合区域早泥盆世火山岩组合(玄武安山岩−安山岩−英安岩−流纹岩),以及广泛出露的同时代的花岗岩基,多数学者认为该地区的早泥盆世处于碰撞后伸展阶段[37]。区域内在夏日哈木铜镍矿床南东方向约13 km的苏海图,发现了411 Ma的榴辉岩[39],夏日哈木岩浆铜镍硫化物矿床成岩成矿定位于碰撞后伸展环境相对比较符合客观实际。东昆仑岩浆弧的形成于450~430 Ma完成,在昆北造山带的东部,发现有榴辉岩约428 Ma[21−23],其他几处蛇绿混杂岩的年龄变化在467~518 Ma,并且这些蛇绿混杂岩的玄武质岩石表现出了典型的MORB特征[21−23,40−42]。由此推测,昆北造山带弧体大约于428 Ma拼贴到柴

达木克拉通的南部边缘。夏日哈木岩浆来源于东昆仑岩浆弧较高程度部分熔融的产物,随着岩浆上涌,地壳S的混入,演化和发展了岩浆产生硫化物的不混溶,最后就位于东昆仑造山带后碰撞构造薄弱部位,形成夏日哈木镁铁-超镁铁质岩体及超大型岩浆铜镍硫化物矿床。

6.2 找矿指向意义

这一认识对于指导找矿具有重要的指向意义。就全球而言,东昆仑夏日哈木岩浆铜镍硫化物矿床是岩浆弧背景发育的最大的镍矿床,启示地质工作者应加强该类型矿床的勘查与研究。从区域找矿着眼,东昆仑夏日哈木外围发育有若干个这样的镁铁-超镁铁质侵入岩体,该矿床的发现和成矿认识对区域内其他岩体的含矿性评价具示范和引领作用,有助于更多新矿床的发现并拓展找矿潜力。在柴达木克拉通西北缘发现了402 Ma牛鼻子梁含矿镁铁-超镁铁质侵入岩体[42],在柴北缘也有类似侵入岩体的发现,并且伴有较好的镍矿化,只是成岩成矿时代尚未确定。这些岩体或者矿床的产出特点就是围绕柴达木克拉通周缘的造山带中,是稳定克拉通边缘的产物,可能与冈瓦纳超大陆的裂解有关,该问题的解决和认识对于指导更大区域的找矿突破具重大研究意义。

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