最新报道

西秦岭双王金矿床与火成碳酸岩成因关系*

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摘 要 西秦岭双王金矿床以大量发育角砾岩型矿石为特征,金与碳酸盐矿物密切共生,在角砾岩之间呈胶结物产出,显示出强烈的幔源特点。长期以来,这种罕见的矿床类型的成因一直困扰着矿床学家。最近,在双王金矿床深部坑道内新揭露的碳酸岩墙,有可能为揭示这一科学难题提供了一个突破口。文章选择碳酸岩和金矿石为研究对象,通过光薄片观察及 TIMA 扫面,发现共生的副矿物锆石、磷灰石和独居石,使利用副矿物的原位微区进行高精度测年解决二者之间的成因联系成为可能。

关键词 地球化学;火成碳酸岩;副矿物;矿床成因;双王金矿床;西秦岭

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Petrogenesis of carbonatite and its relationship to Shuangwang gold deposit

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Abstract

The Shuangwang gold deposit in western Qinling is characterized by a large number of breccia-type ores. The gold is closely associated with carbonate minerals, and they are both present as cementation among breccia and show a characteristic, of strong mantle source. For a long time, the genesis of this rare type of deposit has puzzled the ore deposit scientists. Recently, the newly exposed carbonatite dykes in the deep tunnel of the Shuangwang gold deposit may provide a rare opportunity to shed light on this scientific conundrum. In this paper, carbonatite and gold-bearing ore were selected as research objects, in which zircons, monazite and apatites were found by TIMA scanning. The result provides a guarantee for the genetic relationship between carbonatite and the Shuangwang gold deposit by using in situ microdating with high precision.

Key words: geochemistry, carbonatite, accessory minerals, genesis of the deposit, Shuangwang gold deposit, western Qinling

西秦岭是中国一个重要金矿集区,绝大多数为脉状金矿床,位于西秦岭太白县境内的双王金矿以广泛发育角砾岩而具有特殊性（图1）,其成因一直广受争议,主要观点可归纳为:①卡林-类卡林型（陈衍景等,2004）;② 与深源热液有关,如碱性碳酸岩浆热液交代型（石准立,1993;樊硕诚,1994;贾润幸等,2004）;③ 与韧脆性剪切带相关的深源热液型（腾道鹏,2001）;④ 岩浆作用参与的造山型（毛景文,2001;Wang et al., 2015;2019）;与岩浆热液和幔源热液有关的角砾岩型（谢玉玲等,2000）。实际上,造成上述争议有2个关键因素:① 在双王金矿区未发现与金矿有关的岩浆岩,尽管富有地幔

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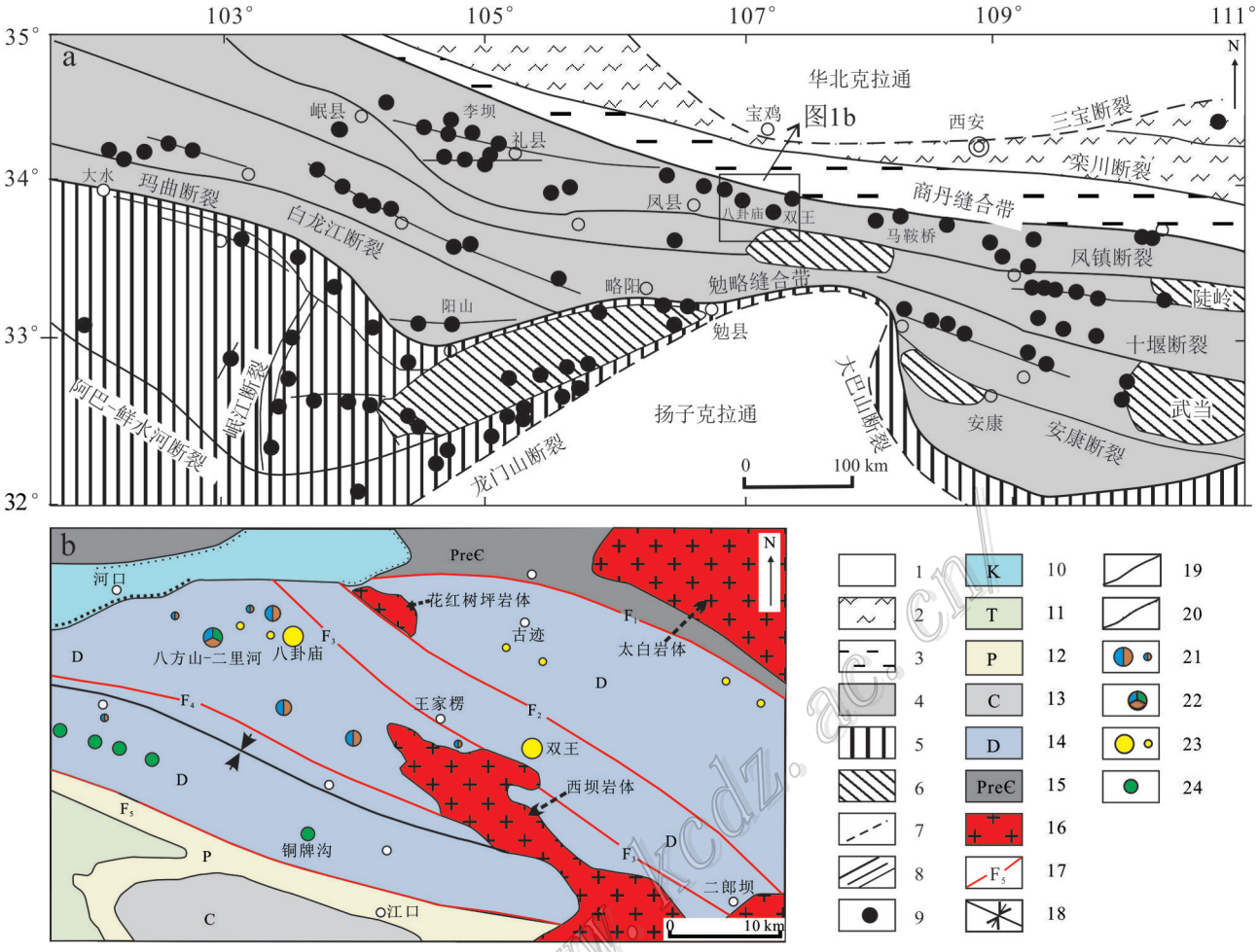

图1 西秦岭构造格架和金矿床分布(a,据陈衍景等,2004;朱赖民等,2009)和凤县-太白县矿集区地质矿产简图(b,据王相等,1996;王瑞廷等,2007;胡乔青等,2013修编)

1—新生代河湖相沉积物;2—中朝克拉通南缘;3—北秦岭造山带;4—南秦岭造山带;5—前陆褶冲带;6—前寒武纪地体;7—克拉通-造山带边界断裂;8—不同尺度的区域性断裂;9—Au储量>20 t的金矿床;10—Au储量为5~20 t的金矿床;11—Au储量为1~5 t的金矿床;12—Au储量<1 t的金矿床(点);13—白垩系砾岩夹碳质页岩;14—三叠系细碎屑岩夹碳酸盐岩;15—二叠系浅变质千枚岩夹灰岩;16—石炭系浅变质千枚岩及含碳硅质岩;17—泥盆系千枚岩、碳酸盐岩及变质杂砂岩;18—前寒武副变质岩、变火山岩及石英片岩;19—印支期—燕山期中酸性侵入岩;20—断层及编号;21—古岔河殷家坝复式向斜;22—地层界线;23—不整合界线;24—铅锌矿床(点);25—铅锌铜矿床;26—金矿床(点);27—铜矿点

Fig. 1 The distribution of tectonic framework and gold deposits in western Qinling (a, modified after Chen et al., 2004; Zhu et al., 2009) and geological map of Fengxian-Taibai ore concentratuiin area (b, modified after Wang X et al., 1996; Wang R T et al., 2007; Hu et al., 2013)

1—Cenozoic fluvial and lacustrine sediments; 2—South rim of the Craton; 3—North Qinling orogenic belt; 4—Southern Qinling orogenic belt; 5—Foreland folding belt; 6—Precambrian terrane; 7—Craton-orogenic boundary fault; 8—Regional faults of different scales; 9—Gold deposits with reserves > 20 t Au; 10—Gold deposits with reserves of 5~20 t Au; 11—Gold deposits with reserves of 1~5 t Au; 12—Gold deposits (ore spots) with reserves < 1 t Au; 13—Cretaceous conglomerate intercalated with carbonaceous shale; 14—Triassic fine clastic rocks intercalated with carbonate rocks; 15—Permian hypometamorphic phyllite intercalated with limestone; 16—Carboniferous metamorphic phyllite and carbonaceous siliceous rock; 17—Devonian phyllite carbonate rock and metamorphic sandstone; 18—Precambrian metamorphic rock, volcanic rock and quartz schist; 19—Indosian—Yanshanian intermediate acid intrusive rock; 20—Fault and its serial number; 21—Compound syncline of Yingjiaba in Guchahe; 22—Stratigraphic boundary; 23—Unconformity; 24—Lead-zinc deposit (ore spot); 25—Lead-zinc copper deposit; 26—Gold deposit (ore spot); 27—Copper ore spot

物质的特点清晰,但来源不明;② 金矿形成时代尚未准确厘定。

双王金矿床的钠长角砾岩型矿化特征在秦岭造山带乃至全球都十分独特。角砾岩中角砾成分主要

为钠长岩和钠长质板岩,具有可拼合性(图 2a),胶结物主要为铁白云石和黄铁矿,含少量石英、方解石和白云石等(图 2b~d),金赋存在胶结物中。陈衍景等(2004)通过对比分析认为双王金矿床为卡林-类卡林型金矿,但后来许多学者相继报道了金矿成矿流体为中高温热液(谢海鹰,2011;刘必政,

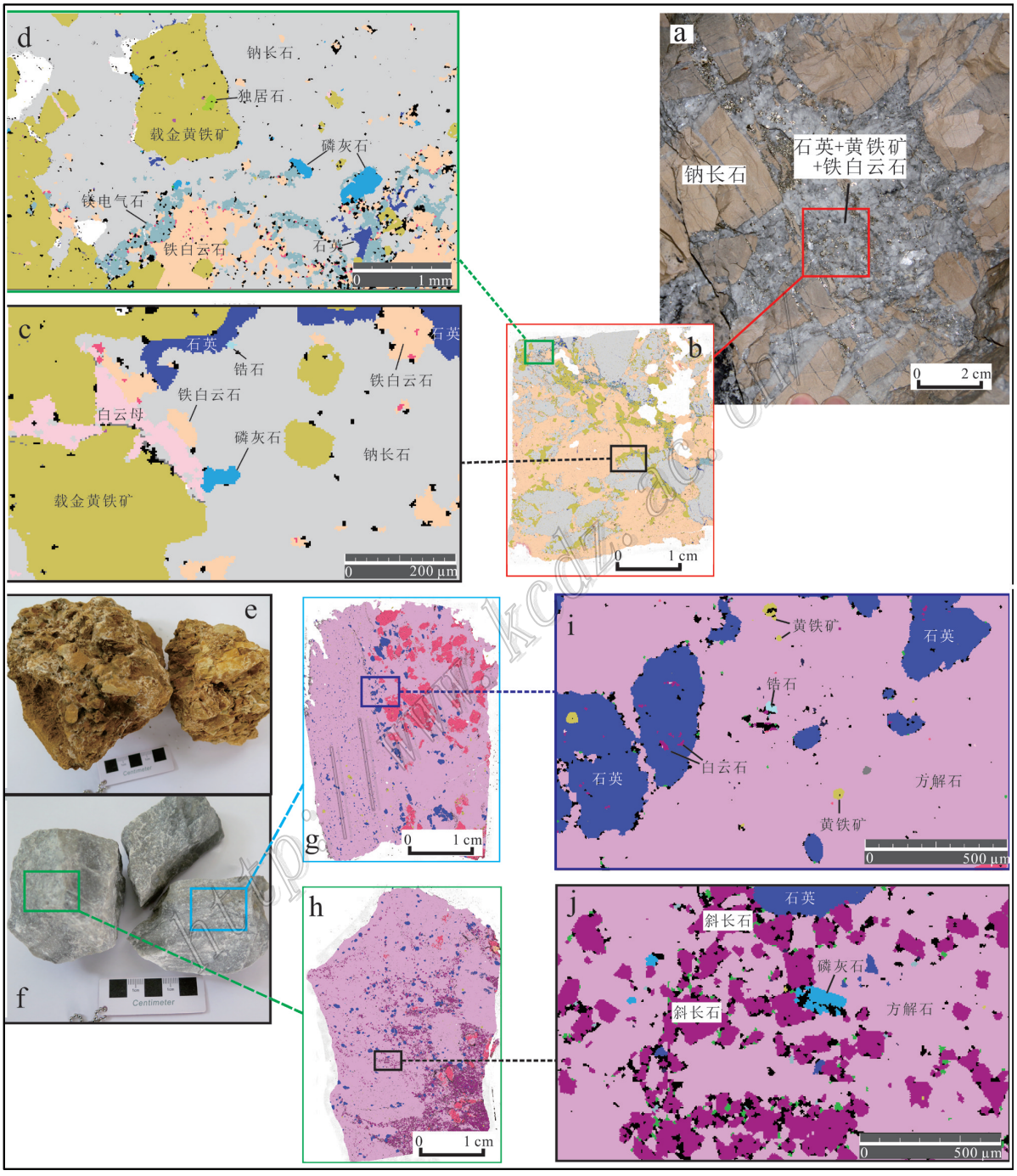

图 2　双王金矿床矿石和碳酸岩的标本照片及副矿物组成

a. 含金角砾岩;b. 矿石薄片 TIMA 测试扫面;c. 矿石中锆石和磷灰石;d. 矿石中磷灰石和独居石;e. 角砾状碳酸岩;f. 块状碳酸岩;g、h. 碳酸岩薄片 TIMA 测试扫面;i. 碳酸岩中锆石;j. 碳酸岩中磷灰石

Fig. 2　The specimen photographs and accessory mineral composition of the ore and carbonatite of the Shuangwang gold deposit

a. Au-bearing breccia; b. TIMA scanning of thin section of ore; c. Zircon and apatite in ore; d. Monazite and apatite in ore; e. Brecciated carbonatite; f. Massive carbonatite; g, h. TIMA scanning of thin section of carbonatite; i. Zircon of carbonatite; j. Apatite of carbonatite

2012；Wang et al., 2019）。稳定同位素组成反映成矿作用与岩浆活动密切相关，成矿流体主要来自于深部，成矿过程中可能有幔源物质的加入（张作衡等，2004；王可新等，2012；汪欢等，2012）。此外，双王金矿床含金角砾岩中的黄铁矿和铁白云石中还发现有铂族元素富集（石准立等，1989；石准立，1993；谢玉玲等，2000；邱士东等，2007），且铁白云石的碳、氧同位素组成与火成碳酸岩基本一致，金矿石及围岩发育强烈碱性-碳酸盐交代蚀变，部分学者提出金直接来自于深部高温富碱的碳酸岩岩浆（石准立，1993）或与碳酸岩岩浆热液有关（樊硕诚，1994）。从成矿热液特征和成矿物质来源等方面来看，前人研究推测其来自深源或者幔源，但却始终缺少深源物质和金成矿关系的直接证据。最近，双王金矿矿区深部坑道揭露了碳酸岩岩墙，那么金矿化与碳酸岩墙在成因上是否存在关系？因此，碳酸岩岩墙的揭露为探索双王金矿成因提供了良好突破口。

成矿时代限定是双王金矿矿床成因研究的一大难题，原因在于2方面：第一是难以直接对自然金矿物进行测年取得精确数据，虽然国外有学者对自然金矿物进行了原位U/Th-^{4}He年龄测定研究（Alexandre et al.，2013），但受限于测试方法尚未成熟，因此尚存在一定的局限性。第二是通过测定含金石英脉中的热液矿物或热液蚀变矿物来确定成矿时代也存在局限。例如，前人研究得到的双王金矿床年龄数据（黄铁矿 $^{40}Ar/^{39}Ar$：（183.09±20.64）Ma、（168±16.2）Ma 和钾长石 $^{40}Ar/^{39}Ar$：202~198.3 Ma）（石准立等，1989；1993），不仅误差大，也难以保证钾长石和金是同一阶段形成。但成岩成矿时代也是解决双王金矿矿床成因的关键，所以，获取高精度成岩成矿时代数据十分重要。

双王金矿区内碳酸岩墙走向延长大于60 m，垂向延深大于370 m，厚度变化在20~73.5 m。区内碳酸岩墙蚀变较强烈，大部分露头呈角砾状（图2e）、砂糖状，部分地方仍可找到较新鲜的碳酸岩（图2f）露头。作者对碳酸岩进行了初步研究，其主要矿物组成为方解石、斜长石、白云石、铁白云石（图2g、h），及丰富的副矿物如锆石（图2i）和磷灰石（图2j）等；其方解石和白云石的碳、氧同位素组成 $\delta^{13}C_{PDB}$ 为−5.6‰~−1.2‰，平均值为−3.6‰；$\delta^{18}O_{SMOW}$ 为14.7‰~19.8‰，平均值为17.8‰，显示与典型的火成碳酸岩组成一致，对比双王金矿主成矿阶段黄铁矿和铁白云石的碳、氧同位素组成，也清楚地反映出双王金矿与深部来源岩浆的联系。此外，通过TIMA测试，在金矿主成矿阶段含金石英脉中找到了锆石（图2c）、磷灰石（图2c、d）和独居石（图2d），为运用副矿物微区测年研究成岩成矿时代及碳酸岩与金成矿作用的关系提供保障。进一步获得高精度的成岩成矿时代数据不仅有望深化金矿成因认识，还可为区内金矿找矿勘查工作提供新的思路。

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