CHEMICAL ENGINEERING TRANSACTIONS

VOL. 62, 2017

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216

DOI: 10.3303/CET1762069

Geochemical Features of Magmatic Rocks and Mineral Deposit Genesis of Xinjiang Aktas Gold Deposit

Lizhi Yang[a,b], Xiangbin Wu[a,b]*, Tiaoli Li[c]

[a]School of Geoscience and info-Physics,Central South University, Changsha 410083, China
[b]Key Laboratory of Metallogenic Prediction of Nonferrous Metals and Geological Environment Monitoring (Central South University), Ministry of Education, Changsha 410083, China
[c]Sinotech Minerals Exploration Co., Ltd. , Beijing 100012, China
wuxb133@126.com

There is a close spatial relationship between the ore body of Aktas gold deposit and the contact zone of the rock body of different periods. This paper by conducting a detailed study of geological and geochemical characteristics with 15 samples of andesitic porphyrite, diorite, slanted granite and medium fine-grained granite, analyzes the relationship between the geochemical features and formation mechanism of magmatic rocks and its mineralization process. It is found that the average content of SiO_2 in volcanic rock of Aktas is 49.69wt%, which suggests that those volcanic rocks are alkaline or calc-alkaline rocks and has no direct influence on mineralization. Besides, the average content of SiO_2 in intrusive rock is 63.17wt%, which means that this kind of rock belongs to medium acid rock, the main source of metallogenic material. The paper also found that the light rare earth is relatively rich while heavy rare earth few, and the LREE/HREE ration of volcanic rock is lower than that of intrusive rock, showing that some crustal substances may be involved in the ascending process of deep magmatic rocks and mixed with mantle material. The source substance of intrusive rock mainly comes from the earth's mantle, therefore the intrusive rock, especially the plagiogranite in this area, may be closely related to the formation of Aktas gold deposit. Combining with the evolution mechanism theory of regional tectonism, this paper concludes that the metallogenic material of Aktas gold deposit originates from the combined action of the ore-bearing fluid from deep mantle and the fluid from shallow crust.

1. Introduction

Altai area has a long mining history and for many years, it has been the focus of local and foreign geological scholars. In addition to abundant storage of gold and rare metal, the region also has large amounts of copper, nickel, iron and mica with high mining value. Some previous states that there are two groups of deep fault zones in Altai area --- the red mountain mouth - Basei - Abagong - Kulti - Kezijiaer -Ertix fault zone and the Kalaxianger - Altai - Baha fault zone. Aktas reign belongs to Ertix mineralization belts and is located on the suture of Siberia plate and Kazakstan plate (Xiao et al., 1992). There are viewpoints holding that this region is located on the fringe of tectonic belt, where frequent crustal movements happen, facilitating mineralization process (Singer, 1993; Wang et al., 1999). Mineralization of epithermal gold deposit in the northern Xinjiang mainly results from gas-liquid metasomatism and magmatic hydrothermal related to magmatism (Liao and Dai, 2000). Aktas gold deposit is located in eastern Altai area, the genetic classification of the alterative mineralized belt and several other Cu-Au deposits below both sides of the coverage area of the ore occurrence mainly belongs to sedimentation-reformation type (Li et al., 2016). So far there are few systematic research on the source of minerals and metallogenic law, and it is necessary to conduct an integrated analysis on the geological and geochemical features and the distribution rule of magmatic rocks in this area as well as the prospecting model (Li et al., 2017; Hou et al., 2017; Huang et al., 2016).

2. Geological setting

The research area is located in the middle of Ural-mongol orogenic belt---the world’s second-largest collisional orogenic belt, which belongs to the jointing part of the kazakhstan plate and the Siberian plate in Tianshan-

Please cite this article as: Lizhi Yang, Xiangbin Wu, Tiaoli Li, 2017, Geochemical features of magmatic rocks and mineral deposit genesis of xinjiang aktas gold deposit, Chemical Engineering Transactions, 62, 409-414 DOI:10.3303/CET1762069

Xingan geosynclinal fold area (Qin et al., 2017). This region has experienced several periods of movement in the history of the earth and eventually closed during the late Paleozoic. After entering the collision-post-collision orogenic evolution stage, this area is characterized with deep magmatic activities originating from mantle. The stratigraphic features in this area are so complicated that it has obvious advantages for mineralization. Most of the strata areas are located within eastern Junggar stratigraphic division, with the emergency of middle and lower Devonian and carboniferous strata. Besides, Ordovician system and Cenozoic groups also scattered widely in this area with normal coverage. All strata in this division did not deteriorate and volcanic rock and volcanic clastic rock of interbedding facies are the main host rocks, with abundant Paleozoic fossils. Cenozoic groups are characterized by continental clastic deposition, among which the Devonian and carboniferous systems are the most widespread, and it’s also the ore-host strata of polymetallic deposits such as copper, silver and gold. The north-eastern part of the research area belongs to Altai stratigraphic division, with several Cambrian, Ordovician, Devonian, carboniferous outcrop and few Permian series and Jurassic series, Paleogene and Quaternary.

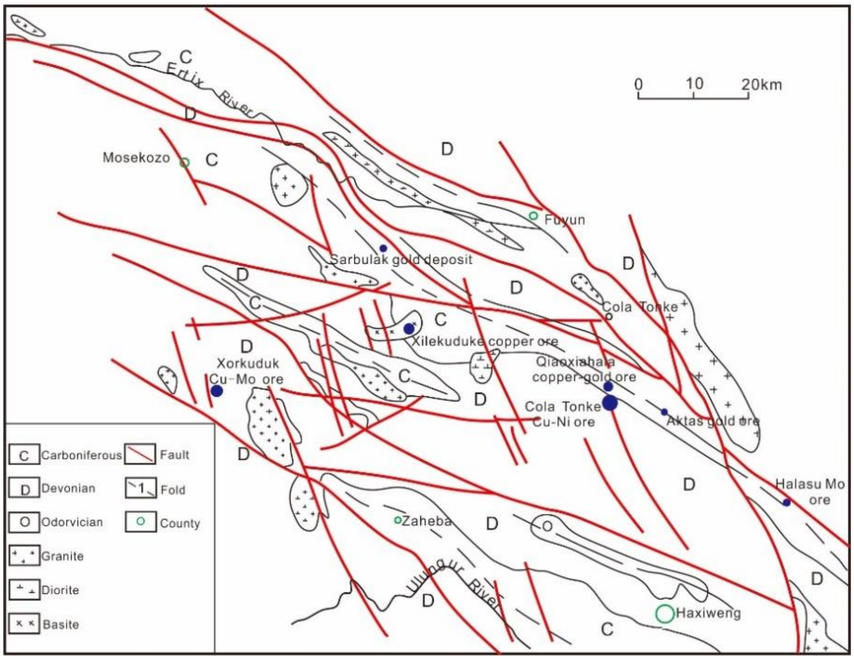

Figure 1: The schematic diagram of regional structure of the study area in Aktas (Wang, 1993)

3. Ore geological characteristics

The ore type of Aktas gold deposit includes gold-copper contained quartz veins, gold-copper contained complex veins, gold-copper contained mixed type and oxidized type. The main ore minerals includes chalcopyrite, pyrite, magnetite, natural gold, natural silver, magnetite, mirror iron ore; secondary minerals includes copper blue, limonite, porphyry copper, malachite; and the gangue minerals includes sericite, calcite, chlorite, quartz etc. Ore structure includes self-shaped and semi-self-shaped grain structure as well as inclusion texture, and the main structure is impregnation-vein impregnated structure.

4. Geochemical features of the magmatic rocks

Since there are frequent tectonic activities in this area, a variety of magmatic rocks are developed, ranging from lutonic and half plutonic rock, pypabyssal rock to eruptive rock, from acid, intermediate, basic to ultra-basic rock (Huang et al., 2016). The main type is Caledonian and Hercynian intrusive rock and the product shapes of its acid rock include batholith, apophysis and dike, mainly belonging to early Hercynian intrusive rock, and accounting for 90% of the magmatic rock coverage. The host rock of Middle Hercynian intrusive rock is basic rock and then neutral rock, and the product shapes include stock and dike distributing along the southern side of the Ertix fault zone, which constitute the Middle Hercynian Karatungk basic complex belt where copper, cobalt, and nickel mineralization happened frequently. There are more rocks containing potassium outcrop in late Hercynian, such as Potassium long granite, black mica granite, black mica keratite granite, granite diorite, and diorite porphyrite. Caledonian intrusive rocks mainly include gabbro, two long granite and slanted granite. Volcanic rocks include later Paleozoic volcanic rocks. Besides, there are also some basal - ultrabasic complex and ophiolite outcrops.

Figure 2: The main magmatic rock types of the research area (a: plagioclenite, b: andesitic porphyrite, c: tuff, d: diorite).

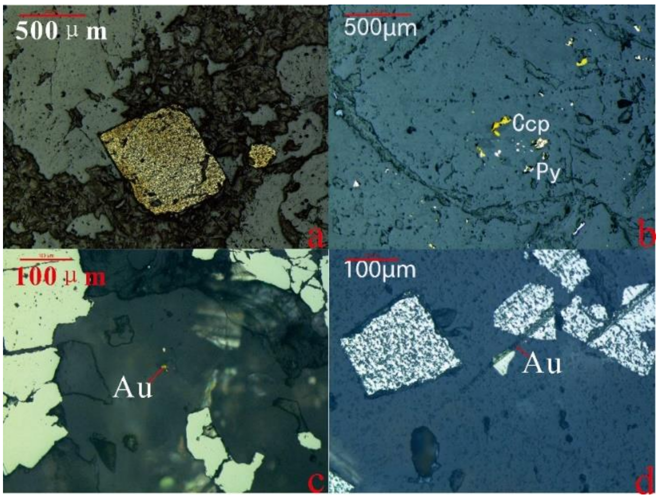

Figure 3: The micrographs of the main gold-bearing minerals of the research area (a: pyrite, b: chalcopyrite, c: gold in the quartz vein, d: Fissure gold in the pyrite & chalcopyrite).

Table 1: The ore type and its mineral assemblage of Aktas

Mineralization stage	Ore type	Mineral composition	Mineral composition		
			Noble metal	Ore minerals	Gangue minerals
Hydrothermal stage	Gold and copper bearing quartz vein type	Native gold-pyrite-chalcopyrite	Native gold-native gold with silver-silver	Pyrite, chalcopyrite and minor bornite, malachite and limonite	Quartz with minor calcite, sericite and chlorite
	Gold and copper bearing mixed type	Chalcopyrite	Native gold-native gold with silver	Pyrite, chalcopyrite; minor magnetite, specularite; and secondary mineral bornite, malachite, azurite, limoite	Quartz, chlorite and sericite with minor calcite
Epidagenetic stage	Oxidation type	Native gold-limonite-covellite-quartz-sericite	Native gold-native silver with gold	Limonite, hematite with minor pyrite, chalcopyrite, magnetite etc.	Quartz with minor calcite, sericite and chlorite etc.

4.1 Major elements

The content of SiO_2 in volcanic rocks is 46.74wt%-53.44wt%, average 49.69wt%; TiO_2 is 0.53wt%-0.89wt%, average 0.78wt%, the variation range of which is lower than that of island-arc tholeiite (average 0.84wt%). The content of MgO is 2.83wt%-7.74wt%, average 4.48wt%; and TFe 7.12wt%-12.29wt%(TFe represent Fe_2O_3+1.111FeO), Al_2O_3 14.79wt%-18.66wt%, average 17.12wt%. The total alkali content of (Na_2O+K_2O) is 2.42wt%-6.34wt%, Na_2O/K_2O 0.85-11.11, average 5.98. The content of SiO_2 in intrusive rocks is 45.33wt%-68.69wt%, average 63.17wt%; TiO_2 is 0.22wt%-0.77wt%, average 0.34wt%; The content of MgO is 0.22wt%-3.06wt%, TFe is 1.35wt%-7.99wt%, Al_2O_3 is13.66wt%-20.44wt%, average 16.01wt%. The total alkali content of (Na_2O+K_2O) is 4.21wt%-13.32wt%, Na_2O/K_2O is 0.75-21.35, average 11.05, belonging to karlsteinite.

Table 2: The Content of the Major elements in ore-bearing rock in Aktas (*wt%*)

Simple ID	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
A9820-1	50.15	0.86	17.04	5.74	4.75	0.15	3.81	10.27	3.46	0.43
A11616-19	46.74	0.83	18.66	4.99	5.75	0.13	5.39	9.7	3.14	1.53
A11616-21	53.44	0.53	19.4	3.26	4.85	0.088	2.83	4.73	4	1.95
A9820-2	52.06	0.77	13.74	4.64	3.35	0.13	3.06	7.28	4.55	0.39
A11616-11a	45.33	0.56	13.66	3.79	0.4	0.2	0.46	18.2	3.82	3.33
A9820-6	68.67	0.24	15.78	1.40	0.6	0.14	0.48	1.3	5.48	5.03
A9820-8	68.69	0.24	15.47	1.60	0.55	0.11	0.48	1.62	5.21	4.34
A11616-12	67.72	0.24	16.37	1.85	0.2	0.04	0.22	1.91	6.8	2.46
A11616-15	67.4	0.25	16.38	1.81	0.35	0.076	0.36	1.72	5.34	4.1
A11620-1	68.41	0.22	15.99	1.19	0.85	0.13	0.52	1.94	5.42	4.28
A11621	68.39	0.34	15.27	1.70	0.65	0.16	0.49	1.58	5.29	4.39
A11621-1	67.97	0.29	16.67	1.80	0.62	0.14	0.51	1.29	5.38	4.98
A11692	68.57	0.34	15.98	1.50	0.59	0.16	0.58	1.19	5.29	5.02
A11616-23	47.11	0.84	19.21	5.05	5.63	0.13	5.44	7.81	4.01	1.29
A11616-22	68.o1	0.24	15.77	1.84	0.22	0.08	0.29	1.81	5.68	3.16

4.2 Trace elements

Through trace element analysis, it can be found that in volcanic rocks, the content of LILE such as K, Th, U, LREE is relatively rich, while HFSE such as Nb, Ta and Ti is depleted, which has the characteristics of island arc volcanic rocks. The ratio of Th/Ta mainly ranges between 2.66~12.56, Ta/Yb between 0.052~0.16, Zr/Nb between 15.81~56.74, and Zr/Y between 3.21~5.88.

The result of rare earth elements analysis shows that the total amount of rare earth elements (∑REE) in volcanic rocks of Aktas is between 69.5~95.18×10-6, average 78.3×10-6. The ratio of LREE/HREE is 3.34~7.21, average 4.86, and the content of light rare earth elements is relatively rich. La/Yb ratio is between 3.72~16.18, which represents that the magma has been fractionated in the process of evolution (Liu, 2017). It is assumed that the fractionation results from olivine, oblique and monocline. the variation range of La/Ya ratio is that light rare earth is rich while heavy rare earth is depleted, and europium, the product of the evolution of homologous magma, is exceptionally inconspicuous. Volcanic rocks are dominated by neutral-basic rock. The total amount of rare earth elements (∑REE) in intrusive rocks is between 89.48~137.30×10-6. The ratio of LREE/HREE is 4.48~13.73, average 7.96, and (La/Yb) N ratio is between 6.17~22.04, which shows light rare earth is rich while heavy rare earth is depleted. The LREE/HREE ratio of intrusive rocks is higher than that of volcanic rocks means that the former probably has crustal substances involvement and is mixed with the mantle material while the latter mainly is the origin of mantle materials.

The composition characteristics of ore containing rock are mainly controlled by substances in the source area. In Fig.3, all Sr-Nd isotope data demonstrates that it has high εNd(t) value, low initial ratio of 87Sr/86Sr, which means that the original magma originated from the depleted mantle source. The isotope value is in the upper right of mantle assembly line and the εNd(t) value is most less than the loss mantle value producing mid-ocean ridge basalt. It is assumed that the original magma from depleted mantle source has mixed variously with crustal substances in the rising and emplacement process, leading low εNd(t) value and similar characteristics of rock mass in Yebu Mountain of Eastern Junggar. It follows that ore magma mainly originates from depleted mantle. The post-impact stretch and squeeze-stretch transition periodin the northern Xinjiang is the peak of massive mineralization, also the period of intense magmatic activity in Junggar area.

5. Relationship between the diagenesis and Mineralization

The rare earth elements and isotopic characteristics in ore-bearing diorite and inclined granite rock are very similar. According to the geological characteristics of the mining area, it's estimated that he formation times of two kinds of rocks is basically the same, and the formation time of diorite is a little earlier than that of plagiogranite. It can be partly observed in the drill that the granite intruded into the quartz diorite, which infers that diorite and granite can be the product of the homologous magma in different evolutionary stages. The diagenetic and mineralization process in this area maybe a continuous magmatic activity process. Metallogenic material from mantle source keeps adding enrichment as magma evolves. In the late stage of magmatic evolution, a lot of crystallization is precipitated out from metallogenic material and ore bodies are formed.

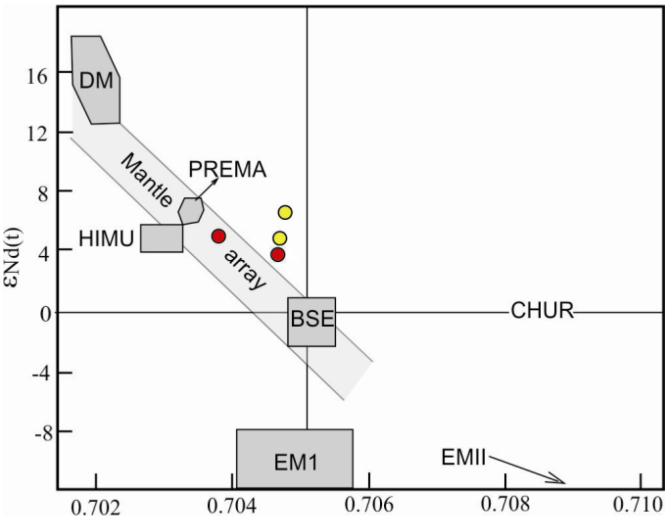

Figure 4: The diagram of Isotope correlation in ore rock of Aktas (Zindler and Hart, 1986) DM-depleted mantle, PREMA-primitive mantle; BSE-Bulk silicate earthHIMU-high U/Pb ratio in mantle; EMI-Type I enriched mantle; EMⅡ-TypeⅡ enriched mantle; CHUR-chondrite

The rock types of gold mineralization include calcareous chlorite schist and calcium sericite, with rare quartz veins. Previous understanding on gold mineralization which states that mineralization information is mainly stored in quartz complex vein is limited to some degree. By combining previous research, the author holds that gold mineralization mainly stores in the relative developmental site of pyrite and chalcopyrite in the outer contact zone between plagiogranite and surrounding rock, while gold quartz complex veins are distributed closely to the outer contact zone of plagiogranite. The occurrence of quartz complex veins is consistent with that of granite contact zone. Therefore, the major ore constraint of gold mineralization in Aktas is rock mass and the main site of gold mineralization is the relative developmental site of pyrite and chalcopyrite in the outer contact zone between plagiogranite and surrounding marble (Wei et al., 2016).

6. Conclusions

(1). Aktas mining area is located in the tectonic binding site of Siberian plate and Kazakhstan - Junggar plate, where the tectonic environment is complex and the magmatic activity develops. The strata outcropped in this area are mainly mud basins and carboniferous systems, and the intrusion of basic-intermediate-acid volcanic rocks and mass magmatic rocks provides the material, heat and power for mineralization, acting as the precondition of accumulation of ore elements in the area.

(2). The Sr-Nd isotopic analysis of plagiogranite in the middle of the mining area shows that ore elements mainly come from mantle and are mixed with crustal substances in rising and emplacement process, increasing the complexity.

(3). Studies on the rock types in Aktas mining area,as well as on the main, trace elements and rare earth elements show that the volcanic rocks in the area have nothing to do with mineralization, instead they only provide space and metallogenic elements . However, plagiogranite is closely related to the gold ore body in time and space, and plagiogranite is consistent with mineraliza tion in diagenetic and metallogenic time. The gold ore bodies is reserved in the plagiogranite, which is the main source of metallogenic materials.

Reference

Hou C.Y., Liu T., Ke G.Q., Chen W., 2017, Geophysical characteristics of Aketasi gold deposit and application of integrated geophysical exploration methods for prospecting in Xinjiang, Mineral Exploration, 8(3), 409-416, DOI: 10.3969/j.issn.1674-7801.2017.03.008

Huang P., Ge J., Duan Z.P., Xu J.J., 2016, Silver ore-dressing model and performance analysis based on anfis, Chemical Engineering Transactions, 51, 205-210. DOI: 10.3303/CET1651035

Huang X.H., Wang C.M., Wang T.Z., Zhang Z.M. 2016. Quantification of geological strength index based on discontinuity volume density of rock masses, International Journal of Heat and Technology, 33(4), 255-261. DOI: 10.18280/ijht.330434

Li J., Guo J.H., Wang Z.X., Liu C.S., 2017, Geochemical and sedimentary setting of the ordovician in central hunan, Chemical Engineering Transactions, 59, 997-1002. DOI: 10.3303/CET1759167

Li T.L., Xiong L.H., Zhang W.S., 2016. Discussion on the relationship between geochemical characteristics and geochronology of granites and mineralization of Aktas gold deposit in Xinjiang, China mine engineering, 45(5), 30-34, DOI: 10.3969/j.issn.1672-609X.2016.05.007

Liao Q., Dai T., 2000, Geochemical characteristics of epithermal gold deposits in northern Xinjiang, Geology-Geochemistry, 28(2), 19-24.

Liu Y., 2017, Chemical and mineralogical study on bastnaesite dominated rare earth ores, Chemical Engineering Transactions, 59, 973-978. DOI: 10.3303/CET1759163

Qin J.H., Zhu B.P., Wu X.G., Jianimuhan A., Zhang X., 2017, Fluid Inclusion and H-O-S Isotopes Study of Wutubulage Gold Deposit in Altay, XinJiang, Xinjiang geology, 35(1), 21-26, DOI: 10.3969/j.issn.1000-8845.2017.01.004

Singer D.A., 1993. Basic concepts in three-part quantitative assessments of undiscovered mineral resources, Nonrenewable Resources, 2(2), 69-81, DOI: 10.1007/BF02272804

Wang F.,1993. Present condition and prospect of copper, gold and multimetal resources in Altay and northern margin of Junggar, Xinjiang, Xinjiang Geology, 11(2), 108-114.

Wang J.B., Deng J.N., Zhang J.H.., 1999, Massive sulphide deposits related to the volcano-passive continental margin in the altay region, Acta Geology Sinica, 73(3), 253-263, DOI: 10.3321/j.issn:1000-9515.1999.03.001

Wei X.F., Yin Y.J., Huang X.K., Ding R.F., Liao Z., Jiang J.P., 2016, 40 Ar/39 Ar dating of the gold-bearing quartz veins in Aketas gold deposit and its geologiacal implications, Xinjiang, Mineral exploration, 7(1), 65-71, DOI: 10.3969/j.issn.1674-7801.2016.01.008

Xiao X.C., Tang Y.Q., Feng Y.M., Zhu B.Q., Li J.Y., Zhao M., 1992, The tectonics in the Northern Xinjiang and its adjacent area, Beijing: Geol. Pub. House, 1-169.

Zindler A., Hart S., 1986. Chemical geodynamics, Annual Review of Earth and Planetary Sciences, 14, 493-571, DOI: 10.1146/annurev.ea.14.050186.002425