Geochemical exploration on the Tareek Darreh Gold deposit, north of Torbat-e Jaam, east Iran

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Abstract

The Tareek Darreh gold deposit is located 40km north of Torbat- e Jaam in the Khorasan-Razavi province,NE-Iran. The study area is mainly comprised of slightly metamorphosed, sedimentary rocks of Jurassic age including alternation of shale, siltstone, and sandstone. These rocks have been intruded by plutonic rocks such as gabbronorite, diorite, quartz-diorite, and rhyodacite. The ore bodes are exposed by trenching and pitting .In this study, all trenches and pits were systematically sampled and analysed by XRF, XRD, ICP methods and petrological and studies for mineralogical characteristics.

The alteration minerals quartz, chlorite, albite, and sericite which are observed mostly on the top or margin of the stocks. Alteration is more intensive at the contacts of the stocks where vein type mineralization has occurred. The veins are mainly composed of silica type and calcite type, arsenopyrite, chalcopyrite, and pyrite main ore minerals. Four promising mineralization zones were selected for further studies. The analytical results for the zones No. 2 and No. 4 confirm high gold, copper, bismuth, tellurium, and silver. In the zone No. 2 (50 x 80 m^2) an average of 3.5ppm gold was recorded for one of the trenches, while In zone No. 4 (50 x 250m^2) The average gold content is 1.35ppm. According to our studies, The Tareek Darreh gold deposit is considered to be similar to the "intrusion-related gold" type.

Introduction

The Tareek Darreh gold deposit is located 40km north of Torbat-e Jaam in the Khorasan Razavi province of Iran. In order to investigate the deposit, first the 1:1,000 mining-geological map of the area was prepared, then several exploration trenches were dug from which 236 samples were taken for ICP and XRD analyses as well as for petrographical and ore microscopic studies.

Geology of the Deposit

According to the 1:1,000 mining-geological map of the deposit, the study area is comprised of three main rock units including 1) Sedimentary rocks, 2) metamorphic rocks, and 3) plutonic rocks. The outcropped sedimentary rocks in the area include an alternation of shale and siltstone (Js). This unit covers a considerable portion in the south, center, west, and north of the area. The unit of red shale and sandstone covers only a small part in the southwest of the area. Alluvial fans (Qt2) and recent alluvia (Qal) comprise the main sediments of the area. The metamorphic rocks cover a small part of the area and are mainly observed in relation to the contact of the plutonic rocks as well as periphery of the large faults. Plutonic rocks cover one third of the study area and are composed of basic to intermediate plutons including quartz-monzonite, quartz-diorite, diorite, gabbro, gabbro-diorite, and gabbro-norite. These rock units are of Jurassic age.

Alteration

Alteration is not pervasive in the study area. The samples taken from the Tareek Darreh area for XRD analysis are mostly indicative of argillic, quartz-sericitic, chloritic alterations (Table 1). These alterations are mainly confined to intrusive rocks, the contact of the plutons and the alternation of shale and sandstone as well as margin of the faults as linear alterations. These zones are sometimes accompanied with arsenopyrite bearing quartz-silica veins. These veins are mainly situated in the gabbro and gabbro-diorite unit. Several silica veins and rhyodacite dikes are also observed in this unit around which alteration traces are observed locally. The quartz-diorite unit with a more acidic composition is possibly the youngest unit among the intrusive rocks of the area. This unit shows some indications of intensive alteration at its contact, although its primary texture has usually been well preserved. The largest extension of the alteration is observed in the plutonic rocks and is often accompanied with brecciation. It seems the fluids have rarely been able to exceed the roof or the contact of the intrusive rocks.

Mineralization and geochemistry

The mineralization in the Tareek Darreh deposit bears a general trend of E-W and is mainly of vein type which is in a close relationship with the contact of the quartz-diorite intrusive rocks and the unit of shale and siltstone. Several arsenopyrite bearing silica-calcite veins have been identified in the crushed zones at the contact of the quartz-diorite. The silica veins are 1cm to several decimeters in size whose arsenopyrite content reaches sometimes up to 90%. Different copper minerals are observed in diverse host rocks almost in all parts of the alteration zones. The copper mineralization is extensively present together with secondary fractures which show the late stage mineralization for such minerals. The ore microscopic investigations indicate arsenopyrite, pyrite, and chalcopyrite as main ore minerals. Native gold was observed only in one section as inclusions in arsenopyrite (Figure 2).

The geochemical analyses (by ICP) introduce gold as the main economic metal of the deposit, while copper, bismuth, and tellurium show also high concentrations. Silver, antimony, and molybdenum are among the other anomalous metals (Table 1).

Statistical parameters

According to the analysis results of the 236 ore and rock samples, gold is the most promising element, while silver, arsenic, copper, bismuth, and tellurium show considerable concentrations whose highest contents are 15.7ppm, 70600ppm, 1540ppm, 25600ppm, and 216ppm, respectively.

The elements whose variation coefficient is more than 100 can be considered as promising or potential bearing elements. In this regard, gold with variation coefficient of 350 has the highest chance after which sulfur, tungsten, bismuth, cobalt, and tellurium can be considered (with variation coefficient from maximum 412 to minimum 287) (Table 2).

The coefficient of correlation for gold is considerable with tellurium, arsenic, bismuth, antimony, and copper, respectively (Table 3). Gold also shows a meaningful coefficient of correlation with cerium.

Conclusions

The Tareek Darreh area (Figure 1) is composed of an alternation of shale and sandstone of Jurassic age into which some intrusives have intruded. Diverse and numerous alterations have occurred at the contact of the intrusive and the country rocks. The alteration is more intense at the contact of the quartz-diorite and gabbro-diorite and their country rocks. The E-W trend of these stocks has caused alterations with the same trend at their contact. The intrusives have been attributed to Jurassic. The alterations are characterized by occurrence of quartz, chlorite, calcite, and sericite and show impregnations of iron- and arsenic-bearing minerals. The presence of arsenopyrite-, chalcopyrite-, and pyrite-bearing silica veins, together with gold in relation to these alterations indicate the significance of this phase of intrusion and its fertility for mineralization. The main mineralization in these veins and altered zones is for gold, arsenic, copper, bismuth, tellurium, and molybdenum. This paragenesis suggests a high temperature for mineralization. The paragensis of mineralization, the form and shape of mineralization, presence of high temperature elements, and setting of the mineralization at the contact of the quartz-diorite and gabbro-diorite is comparable with the Intrusion-related gold system model (Table 4). The correlation of the gold mineralization with tellurium, arsenic, bismuth, and antimony is another indication for high temperature of mineralization. Despite the presence of vast mineralization over the study area, most of the mineralization is of minor economic importance due to small size. Mineralization is only considerable in four zones which have been proposed for further investigations.

Table 1: Summary of the XRD results for the samples of the study area

ردیف	Samples	Major Phases										Minor Phases										Trace Phases	
		Qz.	Sco.	Ano.	Hor.	Mos-Ill.	Chl.	Orth.	Ca.	Mon.	Al.	Orth.	Mon.	Mos.	Mos-Ill.	Al.	Ca.	Goe.	Hor.	Chl.	Qz.	Hor.	Mos-Ill.
1	T4RD-10	*						*		*	*			*				*					
2	TT18D-7									*	*								*	*	*		
3	TT16D-9	*									*				*				*	*			
4	TT18D-7									*	*								*	*	*		
5	TT16D-9	*									*								*	*			
6	TT19D-14	*								*	*							*	*				
7	TT15D-7	*													*	*		*		*			
8	TT14D-5	*								*	*									*		*	
9	TT18D-14	*					*			*	*								*				
10	TT13D-12	*									*				*					*		*	
11	TT9D-7	*				*	*				*								*				
12	TT14D-11	*								*	*									*			
13	TT11D-11	*				*					*	*	*									*	
14	TT13D-13	*					*				*				*								
15	TT5D-4	*									*		*		*					*			
16	TT11D-12	*						*		*	*				*							*	
17	T4SD-6	*					*		*		*											*	*
18	TT1D-15	*					*				*		*		*								
19	TT19D-13										*		*				*		*		*		
20	TT20D-12	*		*			*			*					*			*	*				
21	T4RD-2	*					*				*												
22	T4SD-14	*			*		*				*												*
23	TCHD-5	*	*				*			*						*			*				

Qz.= Quartz, Sco.= Scorodite, Ano.= Anortite, Hor.= Hornblende, Mos.-Ill.= Moscovite-Illite, Chl.= Chlorite, Orth.= Orthoclase, Ca.= Calcite, Mon.= Montmorilonite, Al.= Albite, Mos.= Muscovite & Goe.= Goethite.

Table 2: The statistical parameters of the samples taken form the deposit

(Au in ppb rest in ppm)

Elements	Au	Ag	As	Cu	Mo	Sb	Zn	Sn	W	Bi	Te	Mn	Ni	Pb	Sr	Ba	Fe
N	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183
Mean	1488.1	1.2	3966.4	2516.1	3.9	5.6	83.3	5.0	7.9	47.1	12.0	944.6	25.5	17.5	330.6	471.6	84315.3
Median	40	0.5	443	654	2	2	76.7	3.3	4.1	1.8	0.4	967	20	11.3	331	468	77600
Std. Deviation	5213.9	2.0	11043.4	4471.2	6.8	12.9	44.9	5.9	26.6	154.4	34.5	434.2	21.2	19.6	137.7	231.3	36040.0
Minimum	0	0	21.9	28.9	0.6	0.5	15.2	0.3	0.8	0	0	30	0	0	0.2	4.1	36800
Maximum	52300	15.7	70600	25600	57.6	103	327	59.5	348	1540	216	4210	201	127	625	2580	325000
C.V.	3.50	1.74	2.78	1.78	1.73	2.31	0.54	1.19	3.36	3.28	2.87	0.46	0.83	1.12	0.42	0.49	0.43

Elements	Al	La	Ca	P	Mg	K	Na	S	Co	Cs	U	Hg	Th	Y	Ce	Tl	Rb
N	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183	183
Mean	83432.1	78.2	31081.3	1230.6	21360.1	14454.4	16352.9	2392.3	120.8	9.1	3.0	0.1	7.9	20.3	129.9	0.8	74.4
Median	87600	41	26600	1070	22400	13700	16600	210	27.1	7.2	2.5	0.07	7.93	17.3	75.2	0.8	62.6
Std. Deviation	19330.5	142.0	23802.1	490.8	7805.2	6633.0	6113.4	9845.9	373.6	7.1	1.9	0.2	3.1	15.6	203.0	0.4	47.2
Minimum	3710	0	437	109	121	676	111	0	1.6	1.2	0.49	0	0.61	0.76	6.1	0	3.6
Maximum	117000	1150	221000	2700	36800	53700	33400	111000	3020	39.8	11.7	1.9	19.8	177	1580	2.1	268
C.V.	0.23	1.82	0.77	0.40	0.37	0.46	0.37	4.12	3.09	0.78	0.64	1.90	0.39	0.77	1.56	0.49	0.63

Table 3: Correlation of the elements using Spearman method for the samples taken from the study area (Using ICP method for 44 elements at Zarazma-Amdel)

	Au1	Mn	Pb	Ba	Ti	Fe	Al	K	Mg	Na	P	S	Hg	Ag	As	Bi	Co	Cu	Mo	Sb	Zn	Sn	W	Te	Ce	Tl	Rb
Au1	1.00	0.04	0.23	-0.25	-0.17	0.56	-0.45	-0.11	0.24	-0.46	0.02	0.43	0.49	0.48	0.75	0.15	0.61	0.61	0.49	0.30	0.29	0.46	0.35	0.77	0.50	0.39	0.39
Te	0.77	-0.04	0.35	-0.25	-0.25	0.51	-0.46	-0.11	0.10	-0.44	0.16	0.59	0.56	0.51	0.89	0.83	0.59	0.67	0.51	0.59	0.38	0.57	0.39	1.00	0.40	0.45	0.18
Ag	0.76	-0.05	0.27	-0.25	-0.23	0.71	-0.49	-0.11	0.14	-0.52	0.16	0.61	0.49	0.56	1.00	0.82	0.66	0.68	0.57	0.77	0.30	0.52	0.49	0.84	0.45	0.46	0.30
Bi	0.76	-0.23	0.56	-0.25	-0.40	0.56	-0.55	-0.27	-0.03	-0.21	-0.22	0.61	0.34	0.89	0.82	1.00	0.54	0.56	0.38	0.76	0.27	0.50	0.57	0.59	0.34	0.39	0.23
Sb	0.70	-0.25	0.29	-0.25	-0.41	0.58	-0.67	-0.22	0.05	-0.52	0.13	0.61	0.41	0.56	0.71	0.76	0.54	0.52	0.53	1.00	0.17	0.46	0.35	0.69	0.40	0.28	0.24
Cu	0.61	-0.27	0.24	-0.21	-0.13	0.83	-0.57	0.04	0.17	-0.36	0.12	0.54	0.25	0.68	0.68	0.56	0.55	1.00	0.57	0.52	0.51	0.64	0.44	0.67	0.30	0.59	0.31
Co	0.61	0.21	0.28	-0.25	-0.05	0.52	-0.33	-0.26	0.40	-0.44	0.03	0.33	0.32	0.38	0.65	0.54	1.00	0.55	0.31	0.54	0.44	0.25	0.10	0.65	0.55	0.22	0.24
Fe	0.56	0.14	0.18	-0.24	0.02	1.00	-0.46	-0.16	0.32	-0.56	0.12	0.51	0.32	0.54	0.71	0.56	0.52	0.83	0.52	0.58	0.42	0.49	0.35	0.61	0.41	0.42	0.29
Ge	0.50	0.44	0.24	0.00	0.05	0.41	-0.05	-0.05	0.47	-0.26	0.28	0.07	0.40	0.04	0.43	0.34	0.55	0.30	0.17	0.40	0.42	0.23	0.13	0.40	1.00	0.25	0.44
Ag	0.48	-0.27	0.34	-0.20	-0.29	0.54	-0.50	-0.23	-0.05	-0.42	-0.21	0.54	0.25	1.00	0.53	0.49	0.38	0.63	0.39	0.59	0.40	0.52	0.41	0.64	0.09	0.35	0.04
Sn	0.46	-0.06	0.30	-0.14	-0.13	0.49	-0.32	0.32	0.00	-0.53	-0.22	0.37	0.17	0.52	0.54	0.50	0.25	0.64	0.49	0.46	0.49	1.00	0.54	0.51	0.23	0.52	0.32
Hg	0.43	-0.25	0.18	-0.22	-0.13	0.32	-0.06	-0.04	0.11	-0.16	-0.07	0.19	1.00	0.25	0.43	0.34	0.32	0.25	0.19	0.41	0.09	0.17	0.51	0.38	0.40	0.34	0.22
Mo	0.43	-0.24	0.56	-0.24	-0.40	0.52	-0.51	-0.24	-0.21	-0.47	-0.22	0.66	0.19	0.39	0.57	0.68	0.31	0.57	1.00	0.53	0.27	0.45	0.30	0.61	0.17	0.26	-0.25
S	0.43	-0.22	0.23	-0.24	-0.44	0.51	-0.50	-0.16	-0.15	-0.25	-0.35	1.00	0.19	0.53	0.51	0.61	0.33	0.54	0.66	0.51	0.28	0.37	0.25	0.58	0.07	0.22	0.08
Tl	0.39	-0.05	0.16	0.08	0.07	0.42	-0.11	0.48	0.20	-0.35	0.02	0.22	0.34	0.35	0.46	0.39	0.22	0.53	0.25	0.28	0.36	0.52	0.50	0.45	0.25	1.00	0.51
Rb	0.39	0.08	0.19	0.05	0.22	0.29	0.09	0.48	0.31	-0.27	0.27	0.08	0.22	0.04	0.20	0.23	0.24	0.31	-0.02	0.24	0.29	0.32	0.19	0.19	0.44	0.51	1.00
W	0.35	-0.23	0.16	-0.25	-0.12	0.35	-0.32	0.33	-0.04	-0.27	-0.31	0.25	0.51	0.41	0.43	0.37	0.10	0.44	0.30	0.35	0.17	0.54	1.00	0.33	0.13	0.50	0.19
Zn	0.29	0.27	0.39	-0.09	0.15	0.42	-0.12	0.04	0.37	-0.26	0.18	0.26	0.09	0.40	0.29	0.27	0.44	0.51	0.27	0.17	1.00	0.43	0.17	0.38	0.42	0.36	0.29
Mg	0.24	0.38	-0.34	0.09	0.42	0.32	0.17	-0.35	1.00	0.06	0.48	-0.15	0.11	-0.05	0.14	-0.02	0.40	0.17	-0.25	0.35	0.37	0.00	-0.14	0.10	0.47	0.20	0.31
Pb	0.23	-0.05	1.00	-0.20	-0.33	0.15	-0.22	0.14	-0.34	-0.23	-0.27	0.33	0.19	0.34	0.27	0.36	0.20	0.24	0.36	0.39	0.39	0.30	0.18	0.35	0.24	0.15	0.19
Mn	0.04	1.00	-0.05	0.15	0.37	0.14	0.20	-0.31	0.76	0.11	0.46	-0.32	-0.05	-0.27	-0.10	-0.29	0.31	-0.27	-0.34	-0.28	0.27	-0.18	-0.32	-0.14	0.44	-0.33	0.09
P	0.02	0.46	-0.27	0.03	0.61	0.12	0.27	-0.23	0.48	0.25	1.00	-0.16	-0.07	-0.23	-0.16	-0.22	0.03	-0.05	-0.10	-0.10	0.18	-0.22	-0.31	-0.16	0.28	-0.08	0.27
K	-0.11	-0.21	0.14	0.49	0.15	-0.15	0.27	1.00	-0.33	-0.05	-0.23	0.19	0.08	0.08	-0.11	-0.07	-0.28	0.04	-0.23	-0.22	0.04	0.35	0.39	-0.11	-0.25	0.48	0.48
Tl	-0.17	0.37	-0.31	0.19	1.00	0.02	0.40	0.16	0.42	0.18	0.61	-0.44	-0.13	-0.26	-0.35	-0.45	-0.18	-0.13	-0.43	-0.41	0.16	-0.13	-0.12	-0.35	0.05	0.07	0.29
Ba	-0.25	0.15	-0.05	1.00	0.19	-0.24	0.47	0.49	0.09	0.32	0.03	-0.28	-0.02	-0.20	-0.29	-0.22	-0.29	-0.21	-0.28	-0.30	-0.05	-0.14	-0.05	-0.25	0.00	0.08	0.05
Na	-0.45	0.11	-0.32	0.30	0.18	-0.26	0.51	-0.05	0.09	1.00	0.25	-0.38	-0.18	-0.45	-0.50	-0.51	-0.40	-0.69	-0.49	-0.52	-0.25	-0.51	-0.27	-0.44	-0.23	-0.36	-0.27
Al	-0.41	0.21	-0.22	0.47	0.40	-0.48	1.00	0.27	0.17	0.51	0.27	-0.56	-0.02	-0.53	-0.69	-0.55	-0.22	-0.37	-0.01	-0.51	-0.12	-0.28	-0.40	-0.48	-0.09	-0.31	0.08

Table 4: Comparison of the Tareek Darreh deposit and the intrusion-related gold systems

Characteristic	*Intrusion-related gold systems (Baker and Long 2001)*	*The Tareek Darreh Deposit*
Geologic setting	*Magmatic provinces known for W-Sn deposits*	*A zone known for W-Au mineralization*
Tectonic setting	*Convergent plate boundaries*	*Location in the collision of the Kopet Dagh and Central Iran plates*
Age	*Middle Cretaceous and after*	*Post Jurassic*
Country rock	*Meta-sedimentary rocks*	*Slightly metamorphosed shale and siltstone*
Characteristic of the intrusives	*Reduced metalouminous felsic to intermediate intrusions*	*Quartz-diorite*
Fluids	*Carbonaceous fluids*	*Silicic and carbonaceous fluids*
Alterations	*Locally restricted, commonly weak hydrothermal alteration*	*Weak hydrothermal alteration*
Metal assemblage	*Gold with elevated Bi, W, As, Mo, Te, and/or Sb,*	*Gold with elevated W, Cu, Te, As, Fe, Bi, Sb*
Sulfide Content	*A low sulfide mineral content, mostly <5 vol%,*	*Mostly <5 vol%,*

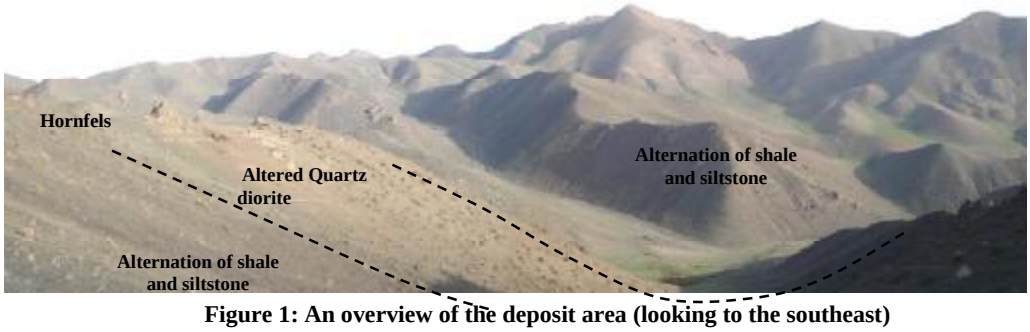

Figure 1: An overview of the deposit area (looking to the southeast)

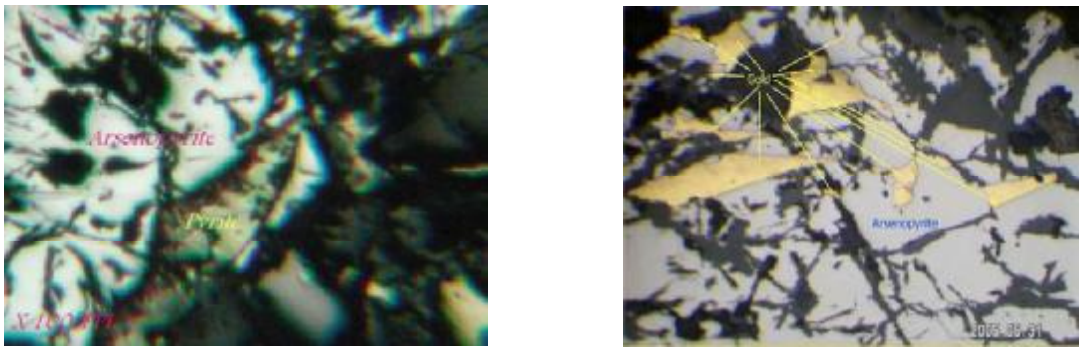

Figure 2: Pictures of some ore minerals of the deposit; right) Pyrite, and Arsenopyrite, left) Gold in Arsenopyrite