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A Study of Geology and Geochemistry of Trace Elements in Central Alborz Coals, Northern Iran

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ABSTRACT
This study focused on bituminous coals of Galandrud region of central Alborz in northern Iran. Coals of this region within carbonaceous sediments of Shemshak formation with the age of upper Triassic-lower Jurassic have been deposited in the form of 32 coal beds. These coals are characterized by relatively high percentage of ash content (6.40-12.73%), high volatile matters (33.32-37.45%) and calorific value (7430-8880 kcal kg^{-1}). Total sulphur amount of Galandrud coals is low (0.45-1.01% wt.) which indicate this region's coals have been deposited in fresh water liminic sedimentary environment. Detected minerals in Galandrud coals are of dolomite (more than 80%), siderite, quartz, sphalrite, galena and kaolinite. Mineral sulphur is seen only in the form of fine and dispersal pyrite within coals of coal layers. Macercals, forming organic part of these coals are mostly of vitrinite (collotelinite) and inertinite (fusinite) group which their pores and fissures have been filled with carbonate and silica. Major elements correlate positively with ash contents demonstrating an association with inorganic constituents. Based on statistical analyses, concentrations of the trace elements such as Co (51.3-152.9 ppm), Ba (368-3297.4 ppm), Cr (65.5-194.2 ppm), Mo (5.6-18.2 ppm), Ni (72.9-152.9 ppm) and V (245.5-520 ppm) are higher than world coal average. However, these coals have low concentration of some volatile elements such as As, Hg and U.

Key words: Galandrud coals, geochemistry, trace elements, central Alborz, Iran

INTRODUCTION

Geographically and geologically Iran is a folded plate which is situated between Arabian plate (in south) and Eurasian plate (in north). Current complex structural-sedimentary status of Iran, represent this fact that various part of it, over the time, has gained different geological characteristics and as a result got distinct from each other (Pedrami, 1993). For the first time, Stocklin (1968), divided Iran into several structural zone with different tectonic status, geological and sedimentary history and designated an area of northern Iran which included Alborz mountains and descendent block of Caspian Sea as Alborz zone (Darvishzadeh, 2003). He was of opinion that basement of this zone which itself is considered a part of Iran-Afghan side of Alp-Himalaya trust fold belt in western Asia, is of continental type (Khosrotehrani, 1989).

Under the effect of previous Cimmerien orogenic movements which had been coincided with close-up of Paleo-tethys ocean, situated between plates of Iran and Touran, most part of Iran emerged out of water and became marshy environments resulting in development of mass forests in upper Triassic to lower Jurassic and eventually formation of coal sediments with heteropic compounds (continental-intermediate and marine) in parts of north (Alborz), central (Kerman) and eastern (Khorasan) Iran. These sediments in Iran were designated by Assereto (1966) as Shemshak formation and all coal mines in Iran such as Galandrud in central Alborz is located in that formation (Razavi-Armagani and Moinosadat, 1994).

There is a little information available about geology and petrology of coals in Central Alborz area of Iran especially Galandrud region. Stratigraphic status of central Alborz region with special view on organic petrography and mineralogy of Galandrud coals also primarily was conducted by Zamani (1999), Stasiuk *et al.* (2006) and Goodarzi *et al.* (2006). In this study, the results of previously conducted studies were reported on geology and petrology of coal seams of Shemshak formation in coalfield Galandrud of central Alborz located in northern Iran.

Coal is one of the primary energy source for many developed and developing countries, although its mining, processing, combustion and post combustion waste products increased thermal pollution, particulate release (smog), sulfur emissions, acid rain, greenhouse effect and trace elements emission and may cause environmental and human health problems (Clarke and Sloss, 1992; Karayigit *et al.*, 2000). Recently scientists have become more interested in the causes of these problems to use of coal more efficiently (Finkelman, 1995, 2004; Gurdal, 2008; PECH., 1980; Swaine and Goodarzi, 1995).

Properties and characteristics of coal depend on its combustible organic and inorganic constituents. Among the coal quality parameters, trace elements in coal can have great environmental, economic, technological and human health impacts (Finkelman, 1995; Gurdal, 2008; Swaine and Goodarzi, 1995).

There are several sources of trace elements, both natural (e.g., weathering of rocks, volcanoes, thermal springs) and anthropogenic (e.g., metal mining and smelting, combustion of coal, agricultural activities). These are present in coal in either organic or inorganic forms and most of these elements occur simultaneously in both forms at concentrations that different stages of coalification (Karayigit *et al.*, 2000; Radenovic, 2006; Swaine, 1990). Most elements are associated with the mineral matter in coal and are mostly concentrations in ash; however, certain elements have an organic affinity (Gentzis and Goodarzi, 1997; Karayigit *et al.*, 2000). Finkelman (1995) discusses 25 Potential Environmental Hazardous Trace Elements (PHTEs) in coal, including Ag, As, B, Ba, Be, Cd, Cl, Cr, Co, Cu, F, Hg, Mn, Mo, Ni, P, Pb, Sb, Se, Sn, Tl, Th, V, U and Zn; of which As, Be, Cd, Cr, Co, Hg, Mn, Ni, Pb, Sb, Se and radionuclides such as U, V and Th are identified potentially Hazardous Ari Pollutants (HAPs) by the U.S. Clean Air Act Amendments of 1990.

In Iran, coal deposits with upper Triassic-lower Jurassic age are limited a few regions (Alborz, Kerman and Khorasan) and there is little studies about the geochemistry of trace elements of Iranian coals except a preliminary study of geochemistry of coals in the Loshan coalfield by Yazdi and Shiravani (2004) and a brief reference of geochemistry of four coal samples from northern Iran by Goodarzi *et al.* (2006). The aim of the present study is to investigate the geochemistry of trace elements and geology Galandrud coals in the central Alborz from northern Iran.

MATERIALS AND METHODS

The black coal deposits of world with upper Paleozoic and Cenozoic age are very common but Mesozoic and particularly Jurassic coals are rare (Khosrotehrani, 1989; Bragin *et al.*, 1981). In Iran, coals are Mesozoic (upper Triassic-lower Jurassic) in age and principal coalfields are located at Alborz and Khorasan in the north and at Kerman in the central Iran (Fig. 1).

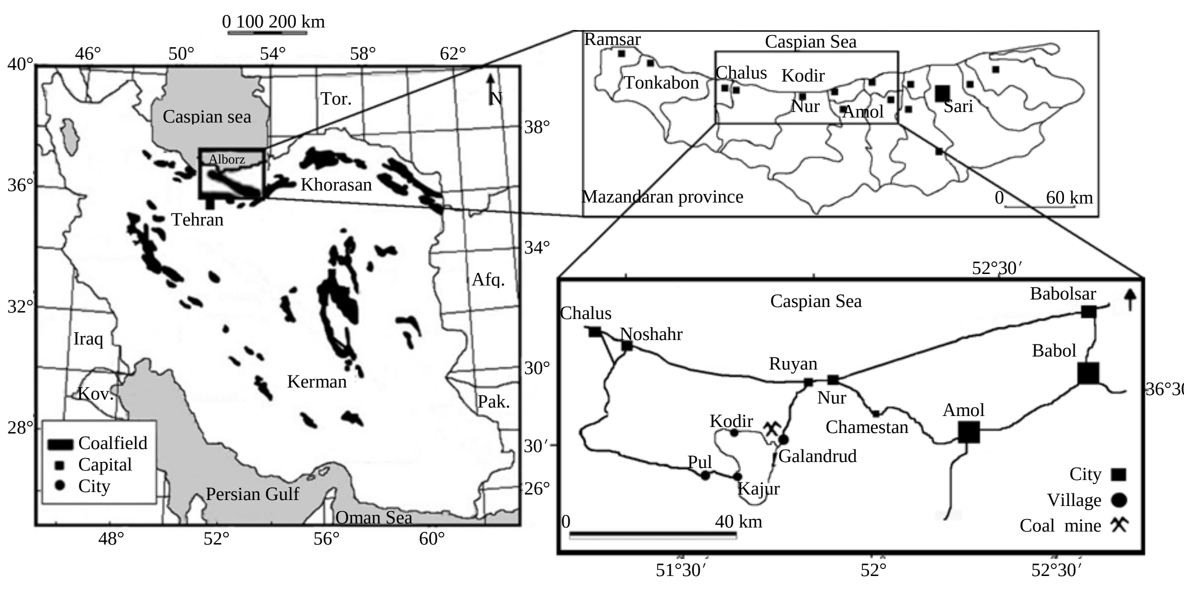

Fig. 1: Location map showing location of Galandrud coals in the central Alborz of Iran

The study area is in the central of Alborz zone from northern Iran. Although, the coal deposits of the Central Alborz have been scattered in various points of this zone, the most extension of coal beds are seen in Galandrud coalfield. The coal-bearing stratums of Galandrud are located on northern slopes of Alborz Mountains and are as far as 20 km south of Rooyan (Alamdeh) town (between 36°34'/36°40'N and 51°19'/51'56'E Fig. 1) in Mazandaran province of Iran. Galandrud coalfield with longitudinal extension of about 100 km have deposited at a high of more than 1240 m from the sea level. Due to the humid climate (average annual rainfall of more than 850 mm) and as a result, expansion of forest covering the Galandrud region, the coal beds are totally masked by dense forest.

Method of study: Six coal samples were taken from Galandrud mine. Standard proximate and ultimate analyses were carried out in the Geological survey and mineral exploration of Tehran, Iran. Mineralogy and petrographical analyses of each coal sample were performed on polished section of coals using a Leitz MPVSP microscope at Geology Department of Baku State university of Baku, Azerbaijan.

The major elements and most of trace elements were analyzed in bulk dried coal samples using ICP-AES (Al, F, Mg, Ca, K, Na, Ti, B, Ba, Cr, Cu, Mn, Sr and V) and ICP-MS (As, Ge, Li, Mo, Ni, Pb, Rb, Sn, Th and U) at the laborators of geological survey and mineral exploration of Iran.

Pearson correlation coefficients using the SPSS statistical program were calculated to determine relationships between concentrations of elements and ash yields.

RESULTS AND DISCUSSION

Geological characteristics of Galandrud coalfield: Mesozoic coal sediments of central Alborz with heteropic facies which over time have been formed by replacing each other and its origin is at link with a sediment megacycle which has been started from upper Triassic (Karnian) going on to middle of upper Jurassic (Kimmeridgian) (Darvishzadeh, 2003). This sediment megacycle have been along with continuous progresses and regresses of sea so that various facies of sedimentary depositions have been created which in central Alborz zone they have been appeared as formations (Fig. 2) (Razavi-Armagani and Moinosadat, 1994).

In Galandrud region, after the previous Camarian orogenic movements, sea regress at middle Triassic has caused sedimentation of limestone as thick as 1200 m which is known in region as Elika formation. This sediments have been characterized by wide-layer dolomitic limestone with grey colors ranging from bright to dark having intermediate layers of bituminose limestone and yellow-green marles appearing manifestly 50° at East side of above-mentioned region that in most points have tectonic contact with Shemshak coal sediments and sometimes with cretacues sediments (Fig. 2). Such sediments represent littoral environment of Galandrud in time of upper Triassic.

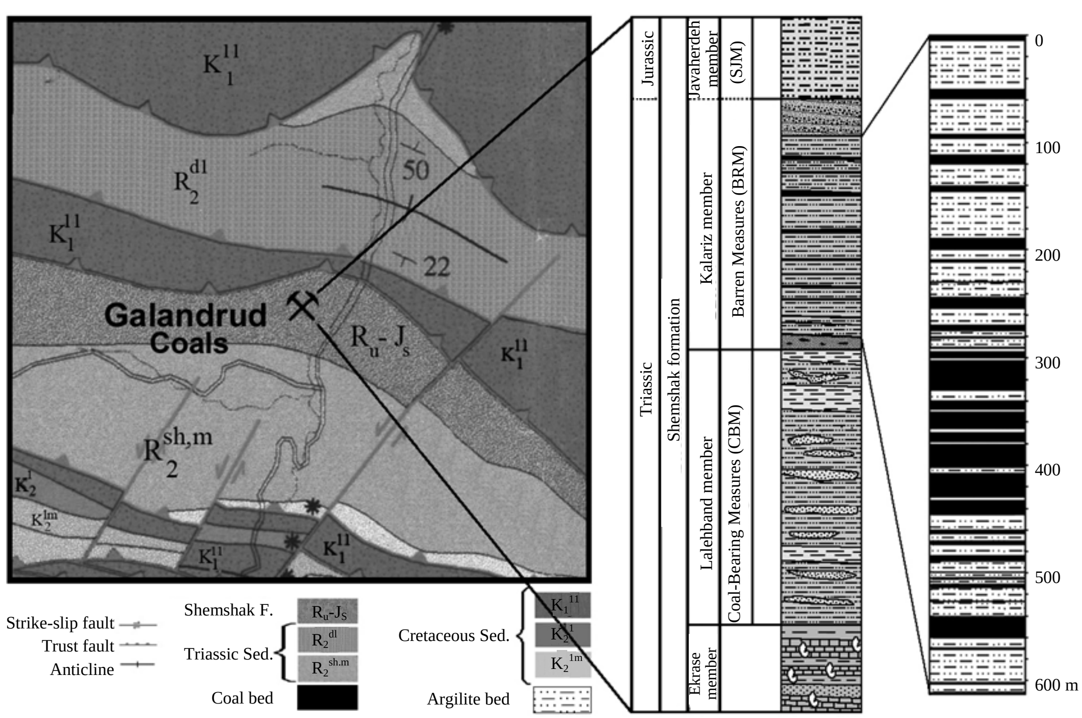

Fig. 2: Generalized geology map and stratigraphic sequence of the Galandrud coalfield

The study of sedimentary rocks of Galandrud region represent this fact that most expansion and dispersion among producing rock-units in region's surface is associated with coal sediments of Shemshak formation which in turn represent incessant sedimentation from upper Triassic to middle Jurassic. This formation in central Alborz is comprised of 4 parts which are folded as syncline structure with axis of WNW-ESE (Zamani, 1999; Zamani *et al.*, 1999). Ekraser part with the same age as upper Triassic (Norian) is comprised of identical layers of argillites, silts with thickness of more than 200 m which its clay limestone layers at lower part contain bioclast as ammonite fossil and represents deltaic-marshy environment. Lalehband part with argillite lithology (siltstone, claystone) has cross-bedding and carbonaceous xylems. Such lithology is characterized by marshy facies (Harami, 1998) and indicates that at Upper Triassic (Rhaetian), marshlands and small ponds locally had been created within central Alborz zone and had deposited sediments like Lalehband part. Thickness of this part had been more than 500 m and with regarding lack or shortage of coal seams, this part is known as BRM (Barren Measures) (Fig. 2).

Main coal-containing part of central Alborz Shemshak formation which is characterized by alternative argillite and silt layers with coal beds. Kalarize part which has had about 600-700 m thickness and has been located between two keybeds of sandstone. These sediments have been deposited in an alluvial-deltaic environment in which conditions for plant growth (as Cycadofites) were provided (Zamani *et al.*, 1999). In Galandrud region, this part of shemshak has 32 coal seams with approximate thickness of 50 cm with mainly Atoctone origin, of which 17 layers are of thicknesses that are workable and due to these characteristics, this section of kalarize part is known as so-called CBM (Coal-Bearing Measures) (Fig. 2). In parts of Galandrud region these stones under the effect of existing faults have been severely broken and fragmented and set as small foldings (Ruhollahi, 1985).

Sediments covering this coal-containing part with lithology of fine and mid-grained conglomerate, big-grained sandstone and tenuous and thickish layers of silt along with fossils of ammonite are indicating existence of marshy-marine environment in the region. This part by thickness of about 300 m is forming Javaherdeh part of Shemshak formation which due to existence of only tenuous coal stringers and carbonaceous plant remnants this part is known as SJM (Super Jacement Measures).

Sea progression in time of Cretacues has caused mass conglomerate sediments be covered by mass fine limestone with marl intermediate layers. These sediments in Galandrud region due to tectonic activities (thrust faults) with tectonic contact are seen adjacent to Shemshak and Elika formations.

Presence of magmatic activities due to tensional phase of previous Cimarian orogeny have caused, in addition hydrothermal metamorphism (often silication) of limestone in region, also coal seams adjacent to these magmatic mass be metamorphosed into coke (Zadkabir, 1992).

Proximate and ultimate analyses: Table 1 summarizes the results of proximate and ultimate analyses of Galandrud coals. The moisture content of coal samples is low and ranges between 0.94 and 1.49%. The ash yield form coal is considered one of main characteristics of coals in Galandrud mine which mainly is in the form of grey, compact particles, varies from 6.40-12.73%. Its high content can be associated with coals formation environment. The coals forming in the marshy environment have high ash yield due to pollution with clastic materials (Thomas, 1992). As whole, Galandrud coals have meltable ash, because of high content of ferroxide, calcium and magnesium (40-60%) (Goodarzi *et al.*, 2006).

The volatile matter contents on an air-dried are high value (33.32-37.45%) that based on the amount of coals volatile matter, according to ASTM (1991) classification, Galandrud coals is within a group of high volatile bituminous B (>31%) (Oslanloo, 1999). Coals of Galandrud coalfield have calorific value (7430-8880 kcal kg^{-1}).

Mineralogy: The studies on polished section of coals show that Galandrud coals mainly contain dolomite (>90%), quartz, sphalerite, galena, pyrite and clay minerals such as kaolinite. The carbonate minerals are commonly syngenetic or rarely epigenetic in origin. The epigenetic carbonates that are resulting from the carbonate bedrock geology occur as cleat-filling as in the Galandrud bituminous coals. The high carbonate content of these coals is reflective of the paleo-geology affecting deposition, because the coal formed as it developed in a terrestrial environment upon an unconformity of eroded limestone and dolomitic rocks (Gentzis and Goodarzi, 1997; Razavi-Armagani and Moinosadat, 1994).

Pyrite in Galandrud coals is rare and is epigenetic and syngenetic forms. The syngenetic pyrite has been determined by framboid texture (Fig. 3d) and epigenetic type is fracture-filling in these coals (Fig. 3c). Sphalerite was determined in the all samples (Fig. 3a), but galena is in only one of the coal sample (Fig. 3b).

In Galandrud's coals, the amount of sulphur (organic and mineral) is so low which they can be considered as low-sulphur coals forming in Liminic sedimentary environment

Table 1: Results of the proximate and ultimate analyses of the Galandrud coals from central Alborz

Parameters	1	2	3	4	5	6	Average
Moisture (%) (ad)	0.94	1.02	1.37	1.49	1.05	1.16	1.17
Ash (%) (ad)	11.28	10.39	12.73	6.40	8.82	8.06	9.42
Volatile matter (%) (ad)	35.93	37.12	33.32	33.53	34.15	37.45	35.25
Fixed carbon (%) (ad)	51.85	51.47	52.58	57.88	55.59	53.33	53.78

ad: Air dried

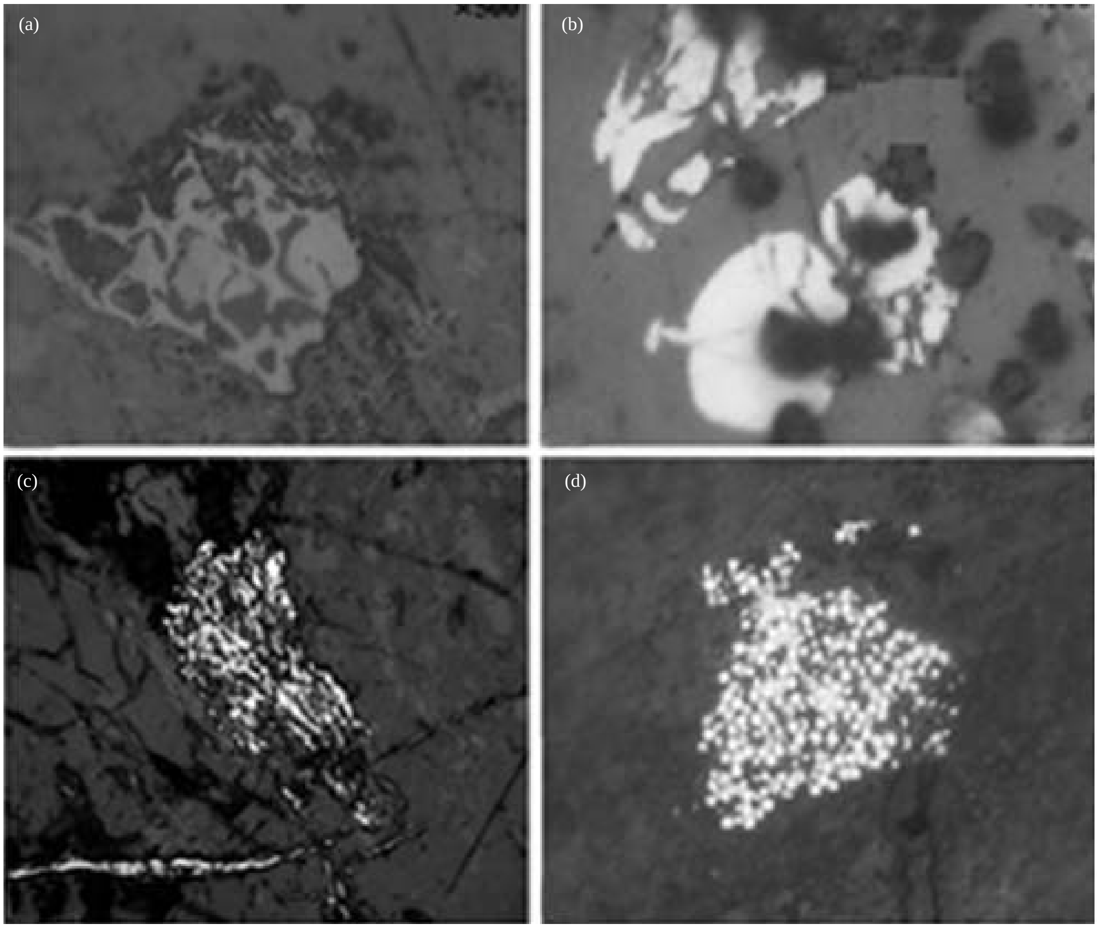

Fig. 3(a-d): Photomicrographs of minerals from Galandrud coals, (a) Sphalerite, (b) Galena, (c) Fractuer-filling pyrite and (d) Pyrite with framboid texture

Table 2: Concentrations of major elements in coal samples of Galandrud region of the central Alborz

Sample No.	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O
	(%)					
1	21.60	20.8	3.1	1.20	1.2	0.10
2	20.80	0.9	5.8	2.70	15.1	0.02
3	17.30	0.5	3.2	1.30	4.6	0.02
4	35.39	12.6	7.6	1.41	7.0	1.14
5	39.24	5.9	6.0	2.97	4.9	1.32
6	28.10	0.4	3.1	0.60	4.0	0.10

with fresh water (Yazdi, 2003). Total sulphur amount of these coals in different coal beds range from 0.45-1.01% weight.

Based on results from study to determine maceral constituent of Galandrud coals vitrinite group (containing more than 30% of collotelinite) forms virtually half of the macerals present in coals (47%) which is not far unexpected given these coals are bituminite. Result of this analysis shows that macerals belong to Inertinite group especially fusinite (25.25%) is in second rank by more than 36% and macerals belong to liptinite group is forming only a few percentage of maceral constituent of organic part in Galandrud coals. Pores and gaps present in macerals are filled by silica and carbonate (Fig. 4).

Results of major element analyses of Galandrud coals are listed in Table 2. The major oxides in coals are dominated by Al_2O_3 (17.3-39.39%), CaO (0.4-12.6%), Fe_2O_3 (3.1-7.6%), K_2O (0.6-2.97%), MgO (1.2-15.1%) and Na_2O (0.02-1.32%).

Results of correlation major elements of Galandrud coals have been shown in Table 3. Although, the element associations may vary from one cola to another, a correlation analyses would demonstrate the general trends. Statically, a low positive correlation (at the 0.99% confidence level) between the element and the ash yield has only been established for K r = 0.30) and the other major elements (Al, Fe, Ca, Mg and Na) show no correlation. Elements that do not correlate with the ash yields probably have different modes of occurrence in the coals studied.

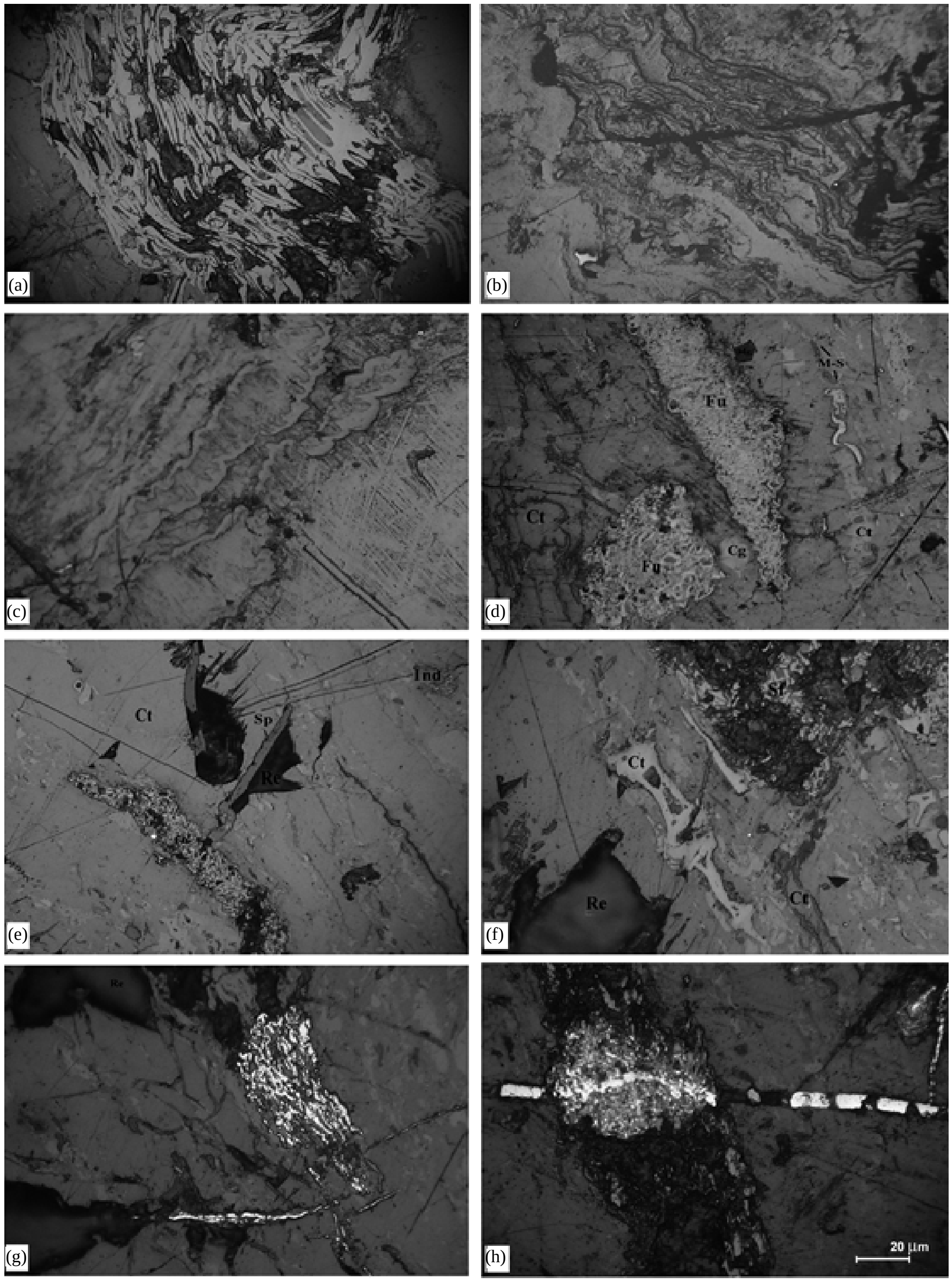

Fig. 4(a-h): Photographs of macerals in Galandrud coal, (a) Collotelinite and Fusinite, (b, c) Collotelinite, (d) Fusinite, Collotelinite, Corpogelinite and Micro-sporinite, (e) Fusinite band, Collodetrinite, Inertodetrinite, Micrinite, Resinite and Sporinite, (f) Semifusinite cell walls filled by clay minerals and calcite, Resinite, Cutinite, Macrinite into Collodetrinite and (g, h) Fusinite band that mineralized cell walls filled by framboid pyrite and fragments other macerals, pyrite mineral had filled crack chambers

Table 3 shows that the Fe, Na and Ca concentrations in the Galandrud coals are higher than those of the other major elements (Al, K and Mg) that appears to be mainly related to the Ca-Fe-Bearing minerals. The coal samples concentration of Fe with K ($r = 0.56$), Mg ($r = 0.52$) and Na ($r = 0.75$) elements has positive correlation that in agreement with the

Table 3: Pearson correlation coefficients (r) between major elements and ash and fixed carbon content of Galandrud coals

	Ash	Fixed carbon	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O
Ash	1							
Fixed carbon	-0.79	1						
Al_2O_3	-0.81*	0.85*	1					
CaO	-0.75	0.95**	0.75	1				
Fe_2O_3	-0.64	0.72	0.64	0.85*	1			
K_2O	0.03	0.06	0.30	-0.17	0.56	1		
MgO	-0.08	-0.11	-0.11	0.06	0.52	0.56	1	
Na_2O	-0.60	0.89*	0.93**	0.85*	0.75	0.42	-0.80	1

*Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level

Table 4: Trace element concentrations of Galandrud coals from the central Alborz of Iran

Elements	1	2	3	4	5	6	Avg.	World coals	Iranian coals
As	21.50	26.90	19.80	31.00	27.10	23.20	24.91	0.5-80	0.4-31
B	1438.20	3931.20	3056.30	1321.00	2164.00	2641.90	2425.43	5-400	-
Ba	1758.60	3297.40	3056.30	368.00	1172.00	2641.90	2049.00	20-100	60-620
Be	7.60	9.10	14.30	21.24	25.13	4.30	13.61	0.10-15	0.27-5.17
Cd	0.10	0.10	0.10	0.64	21.60	0.10	1.00	0.10-15	0.015-1.37
Co	110.80	57.20	75.60	93.90	101.00	51.30	81.63	0.5-30	0.3-20.60
Cr	194.20	65.50	94.10	90.60	128.20	132.00	117.43	0.5-60	15-136
Cu	158.90	59.20	110.20	141.80	205.80	173.20	141.51	0.5-60	5.2-147
Hg	0.19	0.34	0.23	<1.00	<1.00	0.10	0.44	0.02-1.00	0.02-1.51
Mn	275.50	494.10	231.00	532.00	249.00	156.60	323.00	5-300	3.75-420
Mo	5.60	6.10	25.90	8.50	18.60	18.20	13.81	0.1-10	0.16-4.32
Ni	152.90	109.20	151.80	79.60	92.50	72.90	109.81	0.5-50	1.9-58.7
Pb	73.40	45.10	147.70	49.40	88.70	113.20	86.25	2-80	4.3-97.8
Sb	1.80	0.90	1.50	7.11	7.90	0.50	3.30	0.05-10	0.18-3.15
Se	<0.05	0.34	0.23	0.94	<0.20	0.29	0.32	0.2-10	0.75-4
Th	12.10	16.89	11.90	14.70	12.00	11.90	13.25	0.5-10	2.2-21.1
U	1.90	4.40	2.00	4.80	3.50	1.20	2.96	0.5-10	0.5-4.6
V	520.00	245.50	403.70	262.00	321.00	340.20	348.73	2-200	17-214
Zn	82.90	63.20	148.60	120.60	248.20	54.40	99.98	5-300	1.5-553

Results are compared to the ranges for world coals from Swaine (1990) and Iranian coals for Shojaei *et al*. (2007) (ppm)

presence of clay minerals. In coals studied, the highest correlation is between Al and Na elements. These element contents in the coal studied are probably controlled by the abundance of organic matters (macerals).

Models of occurrence of the trace elements and concentration: Trace elements are defined as elements present in coal in amounts of less than 1% of weight and are reported in part per million (ppm) (Swaine, 1990). The concentration of 47 trace and Rare Earth Elements (REE) are determined that has been slown in Table 4. Although, the Galandrud coal samples proved to be enriched relative to most of these elements, in this study, eighteen trace elements in coal including As, B, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Mn, Ni, Pb, Sb, Se, Th, U, V and Zn are evaluated. The range of these trace elements in studied coal samples are compared with the range of world coals (Swaine, 1990) and Iranian coals (Pedrami, 1993).

In Table 4, results of the coal samples analyses show significant enrichment in Co (up to 51.3 ppm), Cr (up to 65.5 ppm), Cu (up to 59.2 ppm), Mo (for three samples, up to 18.2 ppm), Ni (up to 72.9 ppm), Pb (for three samples, up to 88.7 ppm), Th (up to 11.9 ppm) and Mn (for two samples, up to 409 ppm). The higher concentration for B (up to 1438.2 ppm) and Ba (up to 1172 ppm) has been determined which, were associated with the organic affinity. Boron can be a useful index in indicating the palosalinity of coal's depositional conditions (Swaine, 2000). The Galandrud coals are enriched in V (245.5-520 ppm), Co (51.3-110.8 ppm), Cr (65.5-194.2 ppm), Cu (59.2-205.8 ppm) and Ni (72.9-109.2 ppm), compared with the range for most world coals and Iranian coals (Table 4). The result of Yudovich (1972) studies of geochemistry of coals showed that bituminous coals were vanadium type of coals and have high concentration of V, Ti, Ni, Co, Cu and some other trace elements (Yudovich, 2003).

Pearson's correlation coefficients of element concentrations with ash content may provide preliminary information for their organic and inorganic affinities (Table 5). The concentration of arsenic which is one of the most important HAPs elements in coal, is from 19.8-31 ppm and falls within the range for most world coals and Iranian coals (Table 4). Arsenic in the Galandrud coals shows no correlation with ash yields but has positive correlation with Hg ($r = 0.81$), U ($r = 0.87$), Ca ($r = 0.84$) and Fe ($r = 0.96$). In these coals, there is evidence for the organic affinity of As and it is thought that As may be related to Fe-As-oxide (Belkin *et al*., 1997) and some of the minerals such as pyrite.

Cadmium, Se, Sb, Hg, U, Be and Zn are also included in the list of HAPs elements that those contents fall within the range for most world coals and show no correlation with ash yields. From these, the cadmium of the samples correlates with Sb ($r = 0.99$), Zn ($r = 0.89$), Be ($r = 0.82$), Al ($r = 0.81$) and Na ($r = 0.86$). It appears that Cd

Table 5: Pearson correlation coefficients (r) between trace elements and ash content of Galandrud coals

	As	B	Ba	Be	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Sb	Se	Th	U	V	Zn	Hg	Ash
As	1																			
B	-0.02	1																		
Ba	-0.62	0.85*	1																	
Be	0.56	-0.29	-0.67	1																
Cd	0.45	-0.25	-0.57	0.82*	1															
Co	0.10	-0.23	-0.72	0.53	0.46	1														
Cr	-0.43	-0.63	-0.25	-0.24	0.04	0.56	1													
Cu	0.02	-0.69	-0.60	0.33	0.62	0.48	0.64	1												
Mn	0.74	0.04	-0.28	0.27	-0.06	0.06	-0.55	-0.56	1											
Mo	-0.45	0.21	0.25	0.19	0.20	-0.22	-0.13	0.26	-0.66	1										
Ni	-0.71	0.11	0.36	-0.21	-0.35	0.33	0.30	-0.31	-0.18	0.05	1									
Pb	-0.75	0.15	0.39	-0.12	-0.09	-0.20	0.12	0.22	-0.81	0.91*	0.30	1								
Sb	0.49	-0.32	-0.64	0.87*	0.99**	0.53	0.04	0.61	0.01	0.16	-0.33	-0.12	1							
Se	0.71	-0.23	-0.45	0.30	-0.09	-0.09	-0.54	-0.22	0.71	-0.25	-0.52	-0.42	-0.02	1						
Th	0.24	0.75	0.52	-0.26	-0.25	-0.49	-0.57	-0.18	0.56	-0.46	-0.01	-0.52	-0.29	0.04	1					
U	0.78*	0.05	-0.40	0.59	0.34	0.14	-0.60	-0.33	0.90*	-0.47	-0.33	-0.75	0.39	-0.62	0.48	1				
V	-0.78	-0.37	0.07	-0.34	-0.24	0.47	0.83*	0.29	-0.58	0.08	0.73	0.41	-0.23	0.33	-0.50	0.48	1			
Zn	0.17	-0.18	-0.44	0.87*	0.89*	0.52	-0.01	0.50	-0.16	0.47	-0.01	0.21	0.89*	-0.16	-0.38	-0.21	-0.05	1		
Hg	0.82*	-0.37	-0.78	0.93**	0.79	0.48	-0.26	0.31	0.48	-0.09	-0.45	-0.43	0.84*	0.48	-0.12	-0.75	-0.51	0.69	1	
Ash	-0.81	0.45	0.66	-0.32	-0.35	0.01	0.13	-0.39	-0.33	0.25	0.91*	0.47	-0.37	-0.67	0.15	-0.42	0.59	-0.02	-0.59	1

*Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level

may be related to the Cd-bearing minerals, especially sphalerite. The concentration of Ni in coal samples of Galandrud is higher than the world coals and Iranian coals. This element is only element that has positive correlation with ash yield (r = 0.91). Manganese content is between 156.6 and 532 ppm. Most of the Mn in coal, especially bituminous coals, occurs in solid solution in the carbonate minerals (Finkelman, 1994a; Swaine, 1990). In Galandrud coals, Mn correlates with U (r = 0.90) and possibly is relating to organic affinity.

The Pb content range from 45.1-147.7 ppm is higher than both range of world coals and Iranian coals. Lead occurs almost exclusively as galena (PbS) and other Pb-bearing sulfides and possibly also in pyrite (Karayigit *et al*., 2000). In coal samples, this trace element shows positive correlation with Mo (r = 0.91). The Uranium content of Galandrud coals are low (1.2-4.8 ppm) compared to the world coals (0.5-10 ppm) (Yudovich, 2003) and Iranian coals (2.2-4.6 ppm).

The correlation between ash and U content indicates that U has organic affinity. However, it has high correlate with Fe (r = 0.95) as (r = 0.87) and Mn (r = 0.9) which it can be assocated with accessory minerals such as zicon and silicat minerals (Finkelman, 1994b; Gurdal, 2008).

In Table 4, the Th content has been correlated with Mg (r = 0.92), suggesting an association with the clay minerals and monazite which is an accessory mineral in coal (Finkelman, 1995). Selenium content in Galandrud coal samples is in the range of >0.05-0.94 ppm and is low then compared to the Iranian coals (0.75-4 ppm) from Shojaei *et al*. (2007) and is within the range for world coals (Swaine, 1990). The Se not correlated with ash yield which shows organically associated, organic affinity has been inferred by Gluskoter *et al.* (1977) and Finkelman (1994a). However, Swaine (1990) states that Se occurs with sulfide minerals in coal, mainly pyrite (Gurdal, 2008).

CONCLUSION

Coals of Galandrud region, located in central Alborz in northern Iran which have been deposited in a fresh water Liminic sedimentary environment and with humus origin, are of bituminous B with high volatile matter (>33%). In study area, 32 coal beds have been detected, of which 17 are workable. These coals have high ash and low sulphur content. Geological setting played key roles in determinig the geochemistry and mineralogy of Galandrud coals, so that, the mineras in these coals consist mainly of dolomite (>90%) and amounts of siderite, sphalerite, galena, quartz, pyrite and clay minerals.

Macerals of Galandrud coals are mainly vitrinite group (colletelinite) and inertinite group especially fusinite maceral and low amounts of liptinite group macerals.

The concentration of major elements (Al, Fe, Mg, Na and Ca) of Galandrud coal samples have not correlation with ash yield and has only been established for K (r = 0.30). Elements that do not correlate with the ash yields probably have different modes of occurrence in the coals studied.

The contents of trace elements (As, Cd, Hg, Sb, Zn, Se, Be and W) in the Galandrud coals are low compared to world coals and Iranian coals. Most of the trace elements (As, Cd, Co, Cr, Ca, Hg, Mn, Pb, Sb, Se, Zn, B, Ba, Be, Mn, Th, U and V) not correlated with ash yields indicating an organic association and only Ni has positive correlation with ash content indicating an inorganic affinity.

Boron contents in these coals were measured high (1438-3931.2 ppm) indicates that these coals were influenced by sea water due to their deposition. Vanadium, Cr, Co, Cu and Ni in coal samples of Galandrud are also enriched which indicates that these coals are V-type coals.

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