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REGIONAL GEOLOGY AND GEOCHEMICAL CHARACTERISTICS OF UPPER TRIASSIC - LOWER JURASSIC COALS OF THE CENTRAL ALBORZ IN THE NORTHERN IRAN

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This paper presents the characteristics of regional geology and geochemistry of the Galandrud coal samples from the Central Alborz in northern Iran. Coals of this region within carbonate 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 bituminous coals and have low moisture (0.88-1.37%) contents, high ash (12.2-18.6%) yields, a broad range of total sulphur contents (0.45-1.05%$_{wt}$), gross calorific values (7430-8830 kcal/kg) and high volatile matters (28.3-39.3%). The mineral matter of Galandrud coals is mainly made up of dolomite (more than 80%) with amount siderite, sphalerite, galenite, quartz and pyrite. Macerals forming organic part of these coals are mostly of vitrinite (collotelinite) and inertinite (fusinite) group in which the pores and fissures have been filled with carbonate and silica. Major elements have been concentrated in compound of minerals formed in coals of the Central Alborz zone. Concentration some trace elements of Galandrud coal samples including Bi, Co, Cs, Cr, Cu, Eu, Ga, La, Li, Mn, Mo, Nd, Ni, Rb, Sm, Sr, Th, V, W, Y and Yb show anomaly when compared to the world coal values. These elements have organic or inorganic origin and their concentration relative to type of based sediments in central Alborz and hydrothermal activities. In Galandrud coals, as the percentage of coals volatile matters decrease from surface layers toward the bottom layers, the rank of coals increases.

***Keywords**: Galandrud, trace elements, bituminous coal, Shemshak formation, Cental Alborz, Iran*

Introduction

Geologically, Iran is a folded plate situated geographically between Arabian plate (in south) and Eurasian plate (in north). The Current complex structural-sedimentary status of Iran demonstrates that various parts have gained different geological characteristics over the time, and as a result, have become distinguishable from each other [13]. Eshtaklun (1968) divided Iran into several structural zones based on the different tectonic status and geological and sedimentary history. He designated an area of northern Iran which included Alborz Mountains and descendent block of the Caspian Sea as the Alborz zone [2]. He proposed that Basement of this zone which is considered a part of Iran-Afghan side of Alp-Himalaya trust fold belt in western Asia is of continental type [10].

There is very little information available about geology and petrology of coals in the Central Alborz area of Iran especially the Galandrud region. The initial studies of stratigraphic status and tectonic structure of the central Alborz region with emphasis on its carbonaceous sediments were carried out by Buxtrof & Erni (1931) and White et al (1939-40). This research was continued during the following years by other researchers such as Bayat (1969), Vatan & Yassini (1969), Bayat & Agel (1970), Yassini (1981), Paluska & Degens (1992) and Musavi & Ruhbakhsh et al (1997). The study of organic petrography and mineralogy of the Galandrud coals was also primarily conducted by Zamani (1999) and Goodarzi et al (2006). Trace elements with major elements are present in coals at concentrations that differ as a result of the various processes by which they have entered the coal during the different stage of coalification. Most elements are associated with the mineral matter in coal.

However, certain elements have an organic affinity. Elements which associated with mineral matter become variably affected by combustion but are mostly concentrated in a ash [4]. Finkelman (1995) discusses 25 environmentally sensitive elements that may be found in coal in appreciable concentrations. This paper reports the results of the conducted studies on regional geology, petrology and geochemistry of coal seams of the Shemshak formation in the Galandrud coalfield of the central Alborz located in northern Iran [9].

2. Study area

Although the coal sediments of the Central Alborz in some points of this zone have scatter appearance, the most extension of coal beds is seen in the Galandrud region. The coal-bearing strata of Galandrud is located on the northern slopes of Alborz mountains and is 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 the Mazandaran Province of the northern Iran [15]. Coalfield sediments with longitudinal extension of about 100km have been deposited at a height of more than 1240 m from the sea level. Due to the humid climate (average annual rainfall of more than 850mm), expansion of forest covering the Galandrud region, the coal beds are totally masked by the dense forest.

3. Method of study

There are more than 30 coal seams at carbonaceous sediments of Galandrud in the central Elburz. In this study, coal samples were collected from working face of the 17 coal seams which are workable in the Galandrud mine. Samples were air dried, crushed and blended before analyses. Thickness of the observable coal beds and the intermediate layers of the sediments between them were measured to draw stratigraphic column.

Standard proximate and ultimate analyses (using ASTM D 3175 standard) were carried out in Geological Survey Laboratory in Iran. For microscopic and petrography analyses of macerals and minerals, polished and thin sections and X-ray powder diffraction (XRD) were used in order to determine the composition of the Galandrud's coals. Also, we used results from investigation of the same region's coal macerals [18] to determine the percentage of macerals more accurately.

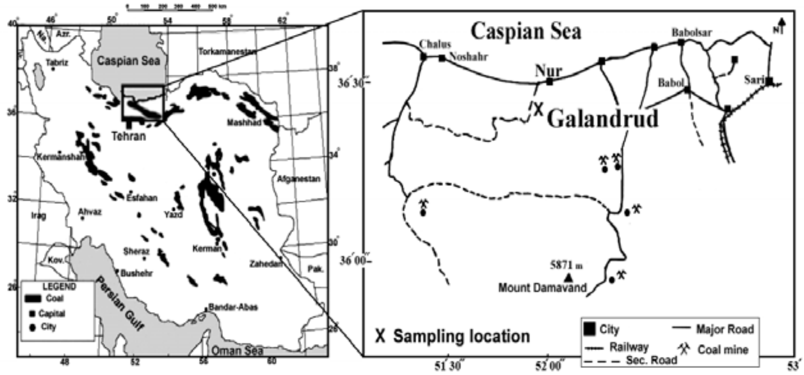

Fig. 1. Location of Galandrud coalfield of the Central Alborz in northern Iran [18].

For the determination of the contents of major and trace elements were used inductively coupled plosma-mass spectrometry (ICP-MS) methods. Pearson correlation coefficients using the SPSS statistical program were calculated to determine relationships between concentrations of elements and ash yield. The significance levels for indicates that, there is either 0.01 or 0.05 probability of the relation between the variables found in the sample set is not valid.

4. Geological setting of the Central Alborz coalfield

Coalfields of the central Alborz such as the Galandrud region occur in upper Triassic-lower Jurassic and part of the Shemshak formation which is similar to other coal-bearing strata of Iran [22]. Coalified sediments of the Galandrud covering approximately 11 km^2 of area are situated along a transverse valley with east-west direction and in the northern and southern portions are adjacent to steep cretaceous lime rocks. Mesozoic coal sediments of the central Alborz, containing heteropic facies, have been formed by replacing each other over the time. Its origin is at link with a sediment megacycle which has been started from upper Triassic (Karnian) continuing to lower of middle Jurassic (Kimmeridgian) [1]. This sediment megacycle has been formed as a result of the continuous progresses and regresses of the sea, so that various facies of sedimentary depositions have been created as formations in the central Alborz zone (Fig. 2) [15].

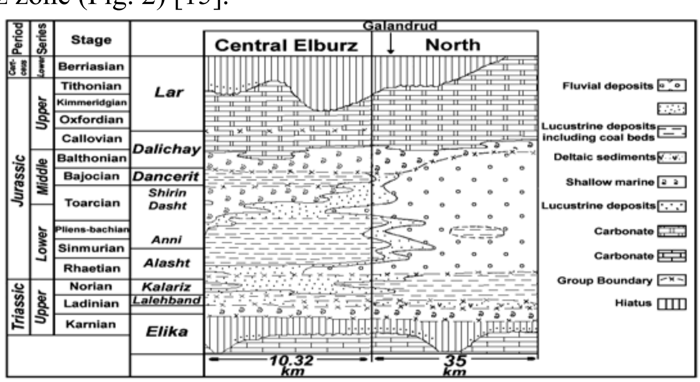

Fig. 2. Cross section of the study area illustrating the stratigraohic relationship of upper Triassic- lower Jurassic in the central Elburz zone of northern Iran [15].

In the Galandrud region, following the previous Camarian orogenic movements, sea regress at Middle Triassic has caused sedimentation of limestone as thick as 1200m, which is known as Elika formation. These sediments have been characterized by wide-layer dolomitic limestone that, in most points, have tectonic contact with Shemshak coal sediments and some times with the cretacues sediments (Fig. 2). Such Sediments represent littoral environment of the Galandrud in time of Upper Triassic.

The study of sedimentary rocks of the Galandrud region indicates that most expansion and dispersion among producing rock-units in the region's surface is associated with coal sediments of Shemshak formation which, in turn, represents incessant sedimentation from Upper Triassic to Middle Jurassic. This formation in the central Alborz is comprised of 4 parts (Ekraser, Lalehband, Kalariz and Javaherdeh) which are folded as syncline structure with axis of WNW-ESE [23].

The Ekraser part has the same age as Upper Triassic (previous Norian) and comprised of identical layers of argillites and silts with thickness of more than 200m. The Lalehband part with argillite lithology (siltstone, claystone) has cross-bedding and carbonaceous xylems. Such lithology characterized by marshy facies [12] and indicates that at Upper Triassic (Rhaetian), marshlands and small ponds had been created locally within the Central Alborz zone and deposited sediments like Lalehband part. Thickness of this part is more than 500m and there is a lack or shortage of coal seams. This part is known as BRM (Barren Measures) (Fig. 3).

It seems that most of a coal beds within the Galandrud mineral deposit to have "in place" origin (Autochtonous) which have been deposited in CBM (middle coal unit) portion of the Kelariz part of the Shemshak group between some layers of sandstone and argillite.

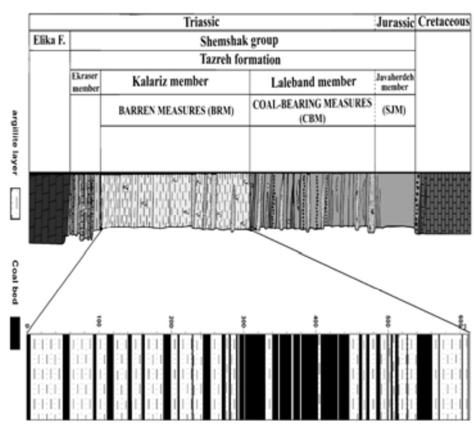

Fig. 3. The generalized stratigraphic sequence of the Galandrud coalfield.

As it shown in the table (2.1) the identified coal beds have not same thickness and some layers in western portion which have considerable thickness, towards east turn into thin coal strips, only the layer 21 which has been spread throughout all parts of the northern edge of the Galandrud region, has uniform thickness and becouse is having constant lithology and keeping distance from intermediate sandstone, it is used as the key bed (layer) to detect other coal beds.

Due to the tectonic nature of region, in most case, coal beds (for example layers 30, 32, and etc) end up in a tectonic line (fault), however, some also is recurred as a coal and argillite layers in full thickness (about several meters) and is revealed as coal beds with composite structure. The thickness of upper sandstone which has a characteristic morphology more than 40m whereas the upper covering unit (SJM) which is consisted of silt sediments only can be seen in the northern edge of anticlean and has up to 300m thickness (Fig. 3).

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

5. Results and discuccion

5.1. Proximate and ultimate analyses

Table 1 summarizes the results of proximate and ultimate analyses of 17 samples taken from the coal beds of the Galandrud coalfield in the Central Alborz. The moisture content of this region's coals varies in the range of 0.88-1.37%, depending on different oxidation degrees of the coals. The ash-remains from a coals varies from 12.2-18.6%.

Table 1

Geochemical properties of the Galandrud coals obtained from proximate [17]

Layer No.	Tickness (cm)	Moisture (%)	Ash (%)	Volatila Matter (%)	Total Sulphur ($\%_{wt}$)	Vitirnite Reflation ($\%R_o$)
1-17	32-114	o.88-1.37	12.2-18.60	29.06-39.30	0.45-1.05	0.88-0.92

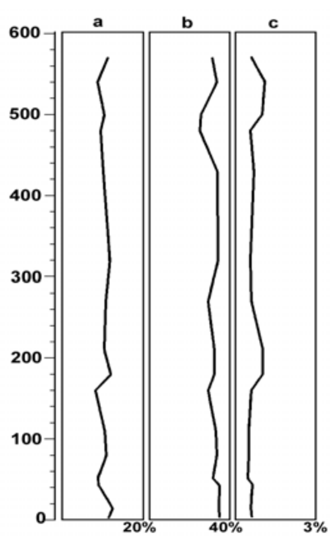

Fig. 4. Geochemical properties variation diagram: (**a**) ash (%), (**b**) volatile matters (%) and (**c**) total sulphur (%wt) of coal beds of the Galandrud coalfield.

The volatile matters content of these coals on an air-dried varies from 28.3% to 39.3% that is a generally increasing from the bottom layers towards the surface in some coal beds (Fig. 4). Based on the amount of the coals' volatile matters, according to ASTM (1991) classification, the Galandrud coals is classified as a group of high volatile Bituminous B (>31%).

In the Galandrud's coals, the level of Sulphur (organic and mineral) is so low that they are considered low-sulphur coals forming in Liminic sedimentary environment with fresh water [21]. Total sulphur amount of these coals in different coal beds range from 0.45 to 1.01 $\%_{wt}$. Calorific value of the Galandrud coals has been estimated between 7430 to 8880 kcal/kg.

5.2. Mineralogy of coal

The surveys done on coals in the Central Alborz show inorganic (mineral) matters of these coals are low and make up only about 12% of the total constituents of coal. Results of the XRD trace and studying thin and polish sections show that, in general, these coals contain:

Carbonate minerals present in a coals of Central Alborz which based on result of XRD analysis make up more than 93% of minerals within coals, mostly are of dolomite and calcite type and sometimes a little siderite also can be seen (Fig.5).

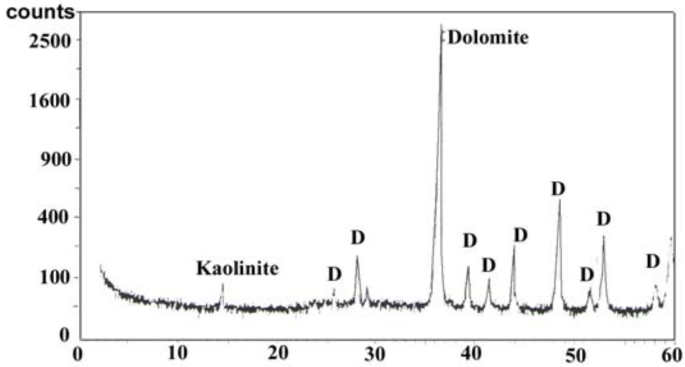

Fig. 5. XRD spectra of Galandrud coal ashed at 400°C consisting of mostly dolomite (D) and minor presence of Kaolinite [7].

Among all sulfide minerals pyrite is found more than other sulfides in the coals, which is made up either as multi-dimension crystals or as primary or secondary form of pyrite flake in the coals. Coals in the Central Alborz are not exception in this matter, but the percentage of sulfide minerals especially pyrite is very low in these coals. This mineral is mostly seen as scattered fine crystals in coal matrix, but in some sections like that is seen in fig. 6_d it has "framboid" texture.

In addition, pyrite mineral in the form of Syngenetic even has been appeared in primary phases of coalification too, and either has been deposited during second phase of coalification as replacing the gaps and cracks within a coals. In coals of the Central Alborz a trivial amount of other sulfide metal minerals like sphalerite, galenite and Chalcopyrite also can be seen in some coal seams which have been placed in adjacency of hydrothermal seams (Fig.6).

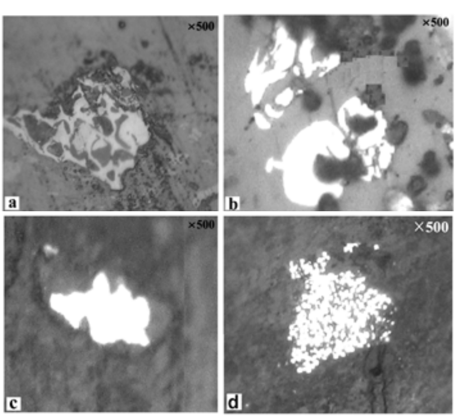

Fig. 6. Sulfide minerals in Galandrud coals, (a) Sphalerite (b) Galenite (c) Chalcopyrite and (d) Pyrite.

Taking into account that most of the minerals such as galenite and sphalerite which contain silver, get separated from hydrothermal solutions in the hydrothermal phase and under the effect of ion-exchange deposit in the chemical constituent of adjacent rock, one can conclude that the presence of such minerals in the different phases of coalification of coals in the Central Alborz can represent the impact of hydrothermal solution and hydrothermal process on the coalification rank of a coals in the Shemshak coal sediments of the Central Alborz (fig. 6).

Quartz is the most plenty silicate mineral which can be seen in a coals of the Central Alborz with fine crystal form into coal matrix.

Given the type of coal sediments in the Central Alborz which is mostly of argillous type, clayey minerals (argillite) is considered an inseparable component of an coals in this region. These minerals which are mostly of the kaolonite and montemorionite type are seen both as separate small lens and in compact form.

4.3. Palynomorphs and macerals of coal

Characteristics of a coals and the dispersed organic matter of the rocks from the region investigated included petrographic composition optical, chemical and technological properties [1]. The average maceral composition of a coals from the Galandrud coalfield of the Central Alborz are Macerals of vitrinite, liptinite (exinite) and inertinite groups.

The coals of the Galandrud region in the Central Alborz zone are of the Bituminite type, macerals of a vitrinite group make up more than 46% of total macerals in these coals [18] and as shown in table 3 from variety of a macerals belong to vitrinite group present in a coals of the Galandrud region of the Central Alborz, collotelinite has the highest percentage (32%) among other macerals (Fig. 7).

Table 3

Maceral analyses for coals from Galandrud coalfield of Central Alborz

Vitrinite group	Telinite	Collotelinite	Collodetrinite	Vitrodetrinite	Corpogelinite	Gelinite	Total
	1.25	32.00	3.25	-	1.25	9.25	47
Liptinite group	Sporinite	Resinite	Cutinite	Exudatinite	Alginite	Liptodetrinite	
	1.00	0.25	2.50	-	-	0.50	4.25
İnertinite group	Smifusinite	Fusinite	Macrinite	Micrinite	Funginite	İnertodetrinite	
	3.75	25.25	0.50	0.75	-	6.50	36.75
Mineral matter	shale	Clay	Carbonates	Quartz	Silica	Pyrite	
	-	-	11.25	0.75	-	-	12

Table 3 shows various macerals of the liptinite group in a coals of the Central Alborz. They are of good coke-producing property and while producing coke are producer of gas in coals

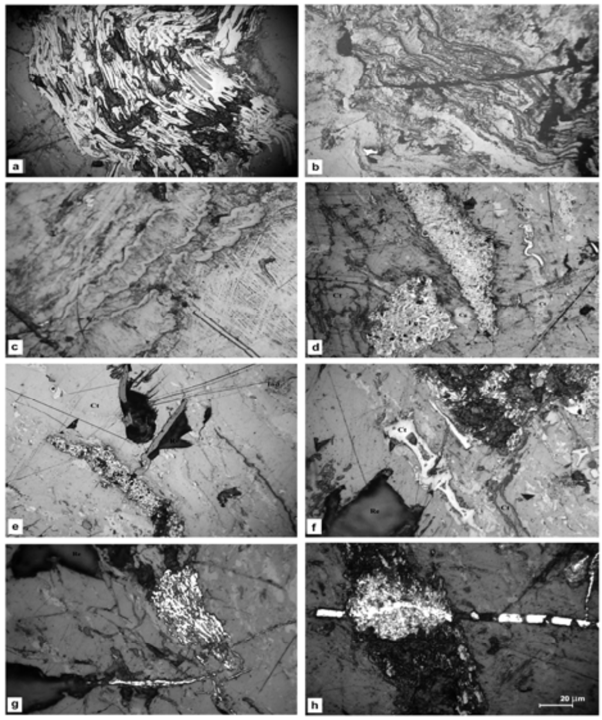

Fig 7. Photographs of macerals in the Galandrud coal: (a) Collotelinite and Fusinite. (b,c) Collotelinite. (d) Fusinite, Collotelinite, Corpogelinite and Micro-sporinite. (e) Fusinite band, Collodetrinite, Inertodetrinite, Micrinite, Resinite and Sporinite. (f) Semifusinite cell walls filled by clay minerals and calcite, Resinite, Cutinite, Macrinite into Collodetrinite. (g,h) Fusinite band that mineralized cell walls filled by framboid pyrite and fragments other macerals, pyrite mineral had filled crack chambers.

[11]. From these macerals, cutinite maceral has the highest percentage and is seen as a secondary maceral in the most of the coal samples (Fig. 7_f).

Fusinite maceral with more than 25% is the most plenty type of inertinite macerals in coal samples taken for study. The empty cell spaces of these macerals in region's coals mostly have been filled with carbonate minerals (dolomite and calcite), clayey minerals (most of kaolinite) and pyrite particles (Fig. $7_{g,h}$).

4.4. Geochemistry of coal

Elements in coals, generally are divided to two major and trace elements groups which their concentration rate in coals is depending on a couple of factors such as: their origin, the environmental conditions under which coal has been derived, type of covering rock and also the volcanic activities in region [4].

4.3.1. Major elements

Major elements within a coals are mostly K, Na, Mg, Si, Ca, Al and Fe which during the development of a coal from plant remains preferably are concentrated more in the mineral compound of a coal than in the organic compound of it. These elements which mostly all in the oxide form take part in the compound of the minerals in a coal, based on the type of a coal's origin and type of an around sediments, have various densities and compositions [9].

Analysis of a coals in the Central Alborz especially the Galandrud region shows that type and value of the major elements within coals of the Central Alborz, which have been given in the table 5, mostly depending on a coals' origin and kind of an around sediments vary in these coal seams. The amount of Fe_2O_3 in a coals of the Central Alborz is 6.4% on average which combined with sulphur has taken part in the formation of the minerals such as pyrite, sphalerite, galenite, siderite and clay minerals in these coals.

Table 4

Major element composition of the Galandrud coals from Central Alborz (ppm)

Sample	**Al_2O_3%**	**CaO%**	**Fe_2O_3%**	**K_2O**	**MgO%**	**Na_2O%**
1	20.99	20.80	6.63	2.28	15.60	1.13
2	35.39	12.60	7.60	1.41	7.00	1.14
3	39.24	15.90	6.00	2.97	4.90	1.32
4	30.51	16.90	5.33	1.33	10.00	1.29
Average	39.30	16.05	6.39	1.99	9.37	1.22

4.3.2. Trace elements

In a coals in an addition to major elements which making their mineral compounds, trace or rare elements also get concentrated in them which although have little density (ppm), are accountable for main geochemical changes of coals [21] and are one the controlling factors of coal's physical properties (color, polish and density). Finkelman in year 1995 after analyzing various coals, proved the concentration of 25 trace or rare elements namely: Pb, P, Ni, Mo, Mn, Mg, F, Cu, Cr, Co, Cl, Cd, Bi, Be, Ba, B, As, Ag, Zn, U, V, Th, Te, Sn, Se, Sb which can get concentrated in inorganic and organic compounds of coals. Concentration rate of trace elements in coals get affected from their origin and environment in which they develop [5] which based on investigation done by Mardon & Hower (2004), Finkelman (2000), Swaine (2000) dispersal of these elements inside inorganic and organic compounds of coals is effective on the quality of detected coals.

Following the study of a coals in the Central Alborz, the concentration of various trace elements in these coals was determined by ICP-Ms analyses which it's results have been given in table 5. These results compared with world standard values determined by Swaine in year 1990. Although it is acknowledged that trace element analyses published subsequent to 1990 will modify the ranges of Swaine (1990), these data remain the best compilation currently available. In addition, concentration these elements compared with ash, total sulphur, volatile matter and fixed carbon contents by Pearson correlation (Table 6).

For Galandrud a coals, S, Ti, Cs, Bi, Ta, Sn, Rb, Th, Te, Se, Yb, U, Mn elements concentration show positive correlation with total sulphur content of coals but Te (0.44ppm) and Bi (56.49ppm) have the most correlation ($r_{sulphur} > 0.9$) with sulfuric compound of a coals in the Central Alborz. These elements which based on table 5 relative to world standard have high concentration, indicating that these are possibly associated with mainly are of inorganic origin and have been concentrated in compound of the minerals within a coals especially sulfuric minerals such as pyrite [8, 16 and 20] But sometimes they can have organic origin too [8].

Table 5

Trace element concentration of Galandrud coals of The Central Alborz.
Results ICP-MS analyses are compared to the ranges for world coals from Swaine (1990) (ppm)

Element	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	Average	World coals Standard
Ag	0.78	6.8	9.04	4.02	9.28	3.34	0.04	1.67	9.99	4.35	6.16	5.54	-
As	-	-	-	-	-	-	-	30	31	271	31	90.75	0.5 - 80
B	141	505	492	391	685	632	279	689	1321	2164	1389	1391	5 - 400
Ba	1765	936	1009	217	677	1474	1185	1441	368	1172	931	978	20 - 1000
Be	10.71	8.45	47.66	1.92	11.93	31.87	11.23	4.44	21.24	25.13	17.38	17.05	0.1 - 15
Bi	19.51	30.1	75.69	129.03	168.59	41.82	24.99	54.12	70.50	38.46	82.87	56.49	2 - 20
Cd	0.45	0.66	5.62	3.55	1.13	0.51	0.50	0.55	0.64	2.16	0.50	0.96	0.1 - 15
Co	22.8	172.2	179.4	48.4	148.8	78.2	29.8	75.7	93.9	101	119	97.40	0.5 – 30
Cr	107.5	23.4	240.4	50.3	101.5	74.7	155.3	46	90.6	128.2	101.8	91.60	0.5 - 60
Cu	125.9	75.4	324.1	23.6	157.8	140.4	222.2	94.9	141.8	205.8	112.6	138.80	0.5 – 6
Dy	2.4	11.3	8.4	7.9	15.4	15.7	1.8	6.4	6.5	16.2	8.3	9.40	0.5 – 4
Ga	39.9	15.7	54.4	11.6	30.9	37.8	43.1	24.1	29.7	42.1	27.2	30.80	1 - 20
Ge	2.02	1.63	0.77	0.92	0.95	1.72	0.99	1.15	1.42	2.7	1.91	1.80	0.5 – 50
Hg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.02 – 1
La	106.8	126.6	88	110.5	234.9	220	93.2	124.4	164	314.8	188.3	197.90	1 – 40
Li	592.7	80.6	211.7	47.2	124.7	586.7	410.5	79.6	516.6	370.9	333.1	325	1 - 80
Mn	2171	293	699	2476	2859	337	266	1462	532	249	500	686	5 - 300
Mo	1.86	2.11	6.83	3.81	4.78	3.5	3.01	4.38	4.08	6.68	3.76	4.37	0.1 – 10
Nd	92.8	27.4	104.3	8.7	101.2	106.8	86.1	47.3	91.6	177.8	98.8	103.90	3 – 30
Ni	39.9	212.7	107.5	73.4	129.2	57.3	25	101.6	79.6	92.5	104.2	94.50	0.5 – 50
Pb	39.7	28.2	204.5	23.9	38.1	28.4	47.3	29.9	49.9	88.7	80.1	62	2 – 80
Rb	55.7	38.3	130.6	179.3	211.2	73.9	61.7	93	115.1	90.3	76.8	93.80	2 – 50
S	2892	38216	20753	61809	25858	29909	1859	16319	21959	9899	18676	16713	-
Sb	4.12	15.85	22.17	2.15	15.98	6	7.09	10.18	7.11	17.90	9.73	11.23	0.05 - 10
Se	<0.2	<0.2	0.95	4.5	3.75	1.09	<0.2	0.69	0.94	<0.2	<0.2	0.82	0.2 - 10
Sm	6	6.1	18	4.6	23.4	18.1	3.1	8.9	12	22.5	10.4	13.40	0.5 - 6
Sn	1.62	1.24	4.33	6.04	7	2.47	1.88	3.31	3.56	2.82	2.53	3.06	1 – 10
Sr	404	3282	387	2983	5767	2283	200	545	8635	4600	4245	4506	15 – 500
Te	0.17	0.35	0.39	0.53	0.37	0.33	0.35	0.49	0.69	0.24	0.33	0.44	-
Ti	11.45	7.67	4.64	7.01	6.55	10.56	3.65	6296	5261	6807	5501	5966.25	-

Continue Table 5

Element	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	Average	World coals Standard
U	-	-	-	-	-	-	-	5.5	4.8	3.5	3.4	4.3	0.5 – 10
V	260	311	520	112	226	224	304	248	262	321	270	275	2 – 200
W	9.94	3.12	7.02	0.9	5.29	8.51	10.44	5.23	9.08	10.16	7.67	8.04	0.5 - 5
Yb	12.6	32.7	12.7	31.4	24.4	27	4.4	22.1	18.8	12.8	20.4	18.5	0.3 – 3
Zn	147.6	162.1	343.3	69.7	118.9	179.7	117.9	75.4	120.6	248.2	150.9	148.80	5 - 300
Zr	726.4	580	1810	142.6	269.4	374.7	897.8	324.9	287.4	655.6	353.1	405.20	-

Table 6

Pearson correlation coefficient between trace elements and ash, total sulphur, volatile matter and fixed carbon of Galandrud coals of Central Alborz

Elemen	Ash	Total sulphur	Volatile matter	Fixed carbon	Elemen	Ash	Total sulphur	Volatile matter	Fixed carbon
		Pearson correlation					Pearson correlation		
	$r_{kül}$	$r_{kükürd}$	$r_{uçucu\ k.}$	r_{Karbon}		$r_{kül}$	$r_{kükürd}$	$r_{uçucu\ k.}$	r_{Karbon}
Ag	-0.95*	0.75	-0.97*	**0.94**	**Nb**	0.66	-0.90*	**0.95**	-0.66*
Ba	**0.93**	-0.80*	**0.98**	-0.90*	**Pb**	-0.41*	-0.50*	0.01	0.49
Bi	-0.42*	**0.94**	-0.84*	0.40	**Se**	-0.15*	0.80	-0.47*	0.05
B	-0.52*	-0.46*	0.00	0.55	**Sb**	0.18	-0.90*	0.68	-0.16*
Co	-0.52*	-0.10	-0.35*	0.61	**Sr**	-0.99*	0.61	-0.87*	**0.96**
Cu	-0.45*	-0.43*	0.08	0.45	**Te**	-0.30	**0.92**	-0.65*	0.21
Ga	-0.36*	-0.54*	0.19	0.37	**Th**	-0.64*	0.84	-0.92*	0.65
Ge	-0.27*	-0.68*	0.25	0.33	**U**	0.40	0.44	0.04	-0.49*
Mn	0.79	0.10	0.40	-0.84*	**V**	-0.27*	-0.67*	0.27	0.31
Mo	0.88	-0.79*	**0.99**	-0.87*	**Zn**	-0.35*	-0.62*	0.18	0.40

* Correlation is significant at the 0.05 level.

In Pearson correlation that Nb, Mo, Ba, Ni elements, shows the highest correlation with ash content of the samples taken from study coals. These elements due to have inorganic origin and accompaniment with minerals of a coal, have high concentration in ash left from it.

The most of trace elements present in a coals of the Galandrud region in the Central Alborz, include V, La, Hf, Co, Ag, Sr, Te, Eu, Cr, W, Be, Y, Pb, Sb, Zr, Dy, As, Cd, Cu, Sm, Nd, B, Zn, Ga, Ge which together with forming fixed carbon of these coals have been high correlation with organic compound of study coals especially Ag (5.54ppm) and Sr (4506ppm) ($r_{carbon} > 0.9$) represents the impact of conditions dominant in formation environment of these coals and also around carbonate sediments of deposited coals seams in the Central Alborz on the rate and way of the concentration of these trace elements in a coals of Galandrud coalfield.

Element B in coals of the Central Alborz with concentration of 1391ppm which is more than three times higher than maximum world coals value determined by Swaine, is used as an index for determining the environment in which the coal has developed [6]. In literature, B is commonly reported as organic associated and/or associated with clay minerals specially kaolinite in coal [3 and 14]. Some of investigators such as Querol et al. (1998) believe that the high concentration of B in a coals is probably a result of synsedimentary volcanic activities which this case due to low correlation of this element with total sulphur of coals in Galandrud coalfield of Central Alborz ($r_{sulphur} = - 0.46$) is rejected.

Conclusions

Coals of the Galandrud coalfield, located in the Central Alborz in northern Iran, with humus origin one of bituminous B with high volatile matters (35%). These coals have been deposited into Shemshak formation with the age o upper Triassic-lower Jurassic in the 32 coal beds which only 17 beds are workable. Galandrud coals have high ash yields and volatile matters and low total sulphur content. Their rank is increased from surface layers to bottom layers with reduction of volatile matters.

The minerals in the Galandrud coals consist mainly dolomite (>90%) and amounts of siderite, sphalerite, galenite, 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 analysed these coal samples show that major elements have concentration with inorganic matters of coals and type of based sediments of the Central Alborz and are indicting an association with carbonate and hydrothermal activities.

Results of Pearson correlation trace elements of Galandrud coals with their ash yields, fixed carbon, volatile matters and total sulphur contents, these elements divided to 3 groups. Some of these elements (Ti, Cs, Bi, Ta, Sn, Rb, Th, Te, Se, Yb, U, and Mn) in Galandrud coals correlate positively with the sulphur content indicating an inorganic affinity. Concentration of Nb, Mo, Ba and Ni elements correlate with the ash yields. The trace element data show that the concentration elements of B, Bi, Co, Mo, Ni, Cr, Cu, Ga, Li, La, Mn, Nd, Sm, Sr, V, W, Y, Eu, Yb and Cs are high compared with the range for most world coals.

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İRANIN ŞİMALINDA, MƏRKƏZİ ALBORZUN YUXARI TRİAS - ALT YURA YAŞLI KÖMÜRLƏRİN REGİONAL GEOLOJİ VƏ GEOKİMYƏVİ XÜSUSİYYƏTLƏRİ

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XÜLASƏ

Məqalədə İranın şimalında yerləşən Mərkəzi Əlborz zonasının Gələndrud yatağı kömürlərinin geoloji, petroloji və geokimyəvi xüsusiyyətlərinə baxılmışdır. Rayonda üst terias-alt yura yaşlı Şemşək formasiyasının karbonat çöküntüləri içərisində yerləşən 32 kömür yatağı müəyyən edilmişdir. Bu kömürlərdə nəmlilik (0.88-1.3%) və kükürdün (0.45-1.05% wt) miqdarları azlıq təşkil edir. İstilikvermə qabiliyyəti (7430-8830 kkal/kg), uçucu komponentlərin (28.3-39.3%) və külün miqdarının yüksək olması təyin edilmişdir. Gələndrud rayonu yataqlarının kömürlərinin mineral tərkibini əsasən dolomit (80%-dən çox), siderit, sfalerit, Kvars və pirit təşkil edir. Bu kömürlərin üzvi hissələrini formalaşdıran inqredientlər əsasən vitrinit (koloterinit) və intertinit (turinit) qruplarına aiddirlər. Onların boşluq və çatları karbonatlarla və kvarsla dolmuşlar. Mərkəzi Əlborz zonasının Gələndrud yatağı kömürlərinin tərkibində B, Bi, Co, Cs, Cr, Cu, Eu, Ga, La, Li, Mn, Mo, Nb, Ni, Rb, Sm, Sr, Th, V, W, Y və Yb iştirak edir. Bu elementlər mənşə etibarilə Mərkəzi Əlborzda yayılmış çöküntülərin növündən başlamış hidrotermal proseslərin fəaliyyətlərindən asılı olaraq üzvi, qeyri-üzvi ola bilərlər. Gələndrud kömürlərində kömürləşmə dərəcəsinin aşağı qatlarında səthə doğru azalması müəyyən edilmişdir.

ПЕТРОЛОГО-ГЕОХИМИЧЕСКИЕ ОСОБЕННОСТИ УГЛЕЙ ВЕРХНЕТРИАС-НИЖНЕЮРСКОГО ВОЗРАСТА ЦЕНТРАЛЬНОГО АЛБОРСА (СЕВЕРНЫЙ ИРАН)

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РЕЗЮМЕ

В статье рассмотрены геологические, петрологические и геохимические особенности углей Каландрудского месторождения Центральной Алборсской зоны. Среди карбонатных отложений Шимшекской формации верхнетриас-нижнеюрского возраста установлены 32 угольных пласта. В этих углях содержания влаги (0,88-1,3 %) и серы (0,45-1,05 %) ничтожны, теплотворная способность высокая (7430-8830 ккал/кг); установлены также высокие содержания летучих компонентов (28,3-39,3 %) и золы. Минеральный состав углей Каландрудского месторождения в основном состоит из доломита (более 80 %), сидерита, кварца и пирита. Ингредиенты, формирующие органическую составляющую этих углей, относятся в основном к группам витринитов (колотеринит) и интертинитов (туринит). Их пустоты и трещины заполнены карбонатами и кварцем.

В составе углей Каландрудского месторождения Центральной Алборсской зоны принимают участие V, Vi, Co, Cs, Cr, Cu, Eu, Ga, La, Li, Mn, Mo, Nb, Ni, Rb, Sm, Sr, Th, V, W, Y и Yb. Эти элементы, в зависимости от типа и деятельности гидротермальных процессов, по происхождению могут быть органическими и неорганическими. Выявлено уменьшение степени углефикации в углях Каландрудского месторождения по мере приближения к поверхности.