PETROGRAPHIC AND GEOLOGICAL CHARACTERS OF THE CENTRAL ELBURZ REGION'S COAL DEPOSITS (ISLAMIC REPUBLIC OF IRAN)

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Abstract:

This study focuses on Bituminous coals (0.80-0.83 Ro %) of Galanderud region of central Elburz 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 (12.2-18.6%), high volatile matters (28.3-39.3%) and calorific value (7430-8880 kcal/kg). Total sulphur amount of Galanderud coals is low (0.45-1.05 %wt which indicate this region's coals have been deposited in fresh water liminic sedimentary environment. Mineral sulphur is seen only in the form of fine and dispersal pyrite within coals of coal layers. Detected minerals in Galanderud coals are of dolomite (more than 80%), siderite, quartz and kaolinite. Macercals, 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. As the percentage of coals' volatile matters decrease from surface layers toward the bottom, the rank of the coals increases. Friction metamorphism is involved in the process of change in coalification rank of coals in Galanderud region. This is due to the presence of tectonic pressures and activity of sub-faults, in addition to regional metamorphism.

1. 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 time, and as a result, have become distinguishable from each other (Pedrami, 1993). Eshtaklun (1968) divided Iran into several structural zones basing on different tectonic status and geological and sedimentary history. He designated an area of northern Iran which included Elburz Mountains and descendent block of Caspian Sea as Elburz zone [1]. He proposed that Basement of this zone which is consideredas a part of Iran-Afghan side of Alp-Himalaya trust fold belt in Western Asia, is of continental type [4].

Due to the effect of previous Cimmerien orogenic movements which had been coincided with close-up of Paleo-tethys Ocean, situated between the plates of Iran and Touran, most part of Iran emerged out of water and became marshy environments. This resulted 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

(Elburz), central (Kerman) and eastern (Khorasan) Iran. Carbonaceous sediments in Iran were designated by Asreto (1966) as Shemshak formation, and all coal mines such as Galanderud in central Elburz are ~~is~~ located in that formation [7]. These sediments are also found in north-west of Iran but they have never been worked out.

There is a very little information available about the geology and petrology of coals in Central Elburz area of Iran especially Galanderud region. The initial studies of stratigraphic status and tectonic structure of central Elburz 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 Galanderud coals also primarily was conducted by Zamani (1991) and Goodarzi et al (2006). This paper reports the results of the conducted studies on geology and petrology of coal seams of Shemshak formation in coalfield Galanderud of central Elburz located in northern Iran.

2. Study area

The coal-bearing strata of Galanderud is located on northern slopes of Elburz mountains and is as far as 20 km south of Rooyan town (between 36°34'/36°40' N and 51°19'/51°56' E Fig. 1) in Mazandaran Province of Iran [7]. These sediments with longitudinal extension of about 100km have been deposited at a height of more than 1240 m from the sea level. Coalfields of central Elburz such as Galanderud region occur in Upper Triassic-Lower Jurassic and part of the Shemshak formation which is similar to other coal-bearing strata of Iran (Fig. 2) [12]. Due to the humid climate (average annual rainfall of more than 850 mm) and as a result, expansion of forest covering the Galanderud region, the coal beds are totally masked by the dense forest.

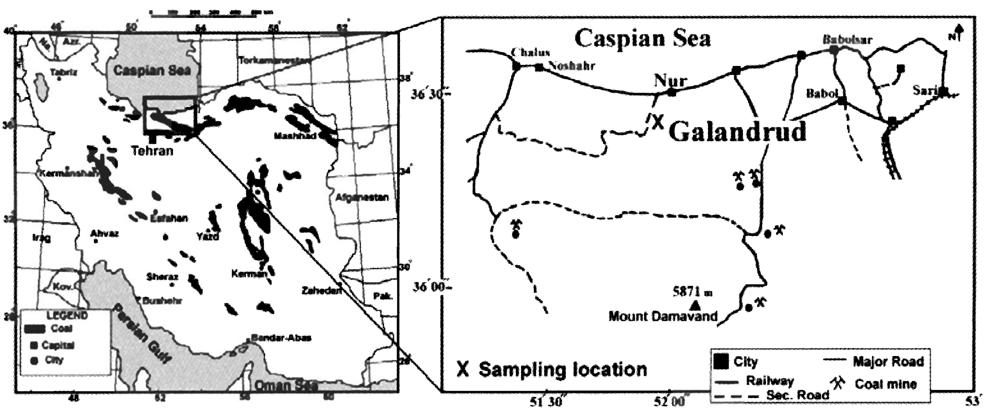

Fig. 1. Location of the Galandrud mine of the central Elburz region of northen Iran. Redrawn after Razavi-Armagani & Moenoalsadat (1994).

3. Method of study

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

Approximate analyses to determine moisture, volatile matters, ash and total sulphur (using ASTM D 3175 standard) of coals were performed in Geological Survey Laboratory in Iran. For microscopic and the petrographic analyses of macerals and minerals, polished and thin sections were used in order to determine the composition of the Galanderud's coals. Also, we used results from investigation of the same region's coal macerals [9] to determine the type and percentage of macerals more accurately. By estimating vitrinite reflection (%R_o), rank of coal samples were also determined.

4.The results and discussion

4.1. Geological characteristics of Galandrud coalfield

Mesozoic coal sediments of central Elburz, containing heteropic facies, have been formed by replacing each other over time. Its origin is at link with a sediment megacycle which has been started from Upper Triassic (Karnian) continuing to Middle of Upper 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 the formations in central Elburz zone (Fig. 2) [7].

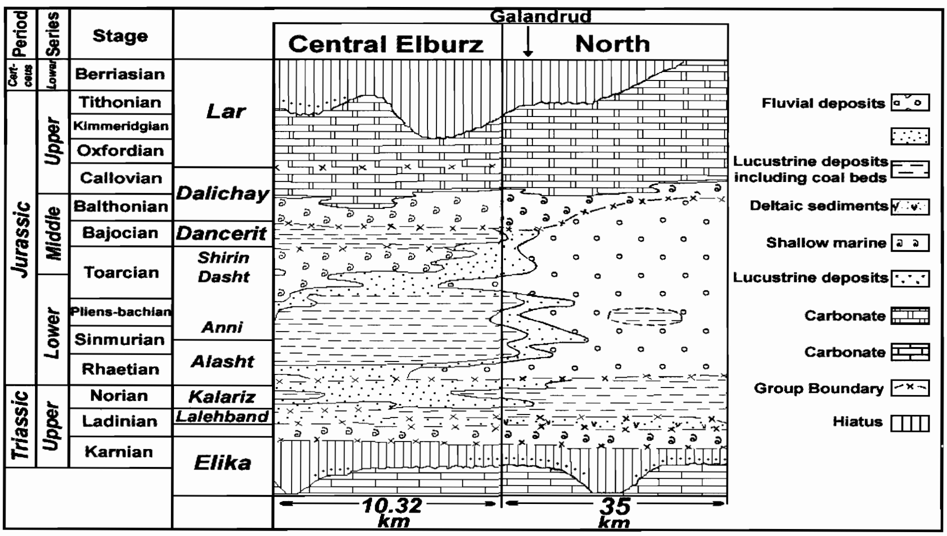

Fig. 2. Cross section of the study area illustrating the stratigraphic relationship of upper Triassic- Jurassic in the central Elburz zone of northern Iran [7].

In Galanderud 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 with grey colours ranging from bright to dark, containing intermediate layers of bituminose limestone and yellow-green marles. They appear manifestly 50° at East side of above-mentioned region that, in most points, have tectonic contact with Shemshak coal sediments and some times with cretacues sediments (Fig. 2). Such Sediments represent littoral environment of Galanderud in time of Upper Triassic.

The study of sedimentary rocks of Galanderud 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 central Elburz is comprised of 4 parts (Ekraser, Lalehband, Kalariz and Javaherdeh) which are folded as syncline structure with axis of WNW-ESE [13]. The Ekraser part has the same age as Upper Triassic (previous Norian) and is comprised of identical layers of argillites and silts with thickness of more than 200m. Its clay limestone layers at lower part contain bioclast as ammonite fossil and represents deltaic-marshy environment. The Lalehband part with argillite lithology (siltstone, claystone) has cross-bedding and carbonaceous xylems. Such lithology is characterized by marshy facies [5] and indicates that at Upper Triassic (Rhaetian), marshlands and small ponds had been created locally within central Elburz 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).

The Main coal-containing part of central Elburz Shemshak group is characterized by alternative argillite and silt layers with coal beds. The Kalarize part with thickness of about 600-700 m has been located between two key-beds of sandstone. These sediments have been deposited in alluvial-deltaic environments which are ideal conditions for plant growth (as Cycadofites) [14]. In Galanderud region, this part of shemshak has 32 coal seams with approximate thickness of 50cm with mainly Atoctone origin, of which 17 layers are of thicknesses that are workable. Due to these characteristics, this section of kalarize part is known as so-called CBM (Coal-Bearing Measures) (Fig. 3).

In parts of Galanderud region, because of existing faults, these stones have been severely broken and fragmented, and set as small foldings [8]. Sediments covering this coal-containing part with lithology of fine and mid-grained conglomerate, big-grained sandstone, and tenuous and thick layers of silt along with fossils of ammonite are indicative of marshy-marine environment in the region. This part with thickness of about 300m is forming Javaherdeh part of Shemshak formation and is known as SJM (Super Jacement Measures), due to existence of only tenuous coal stringers and carbonaceous plant remnants.

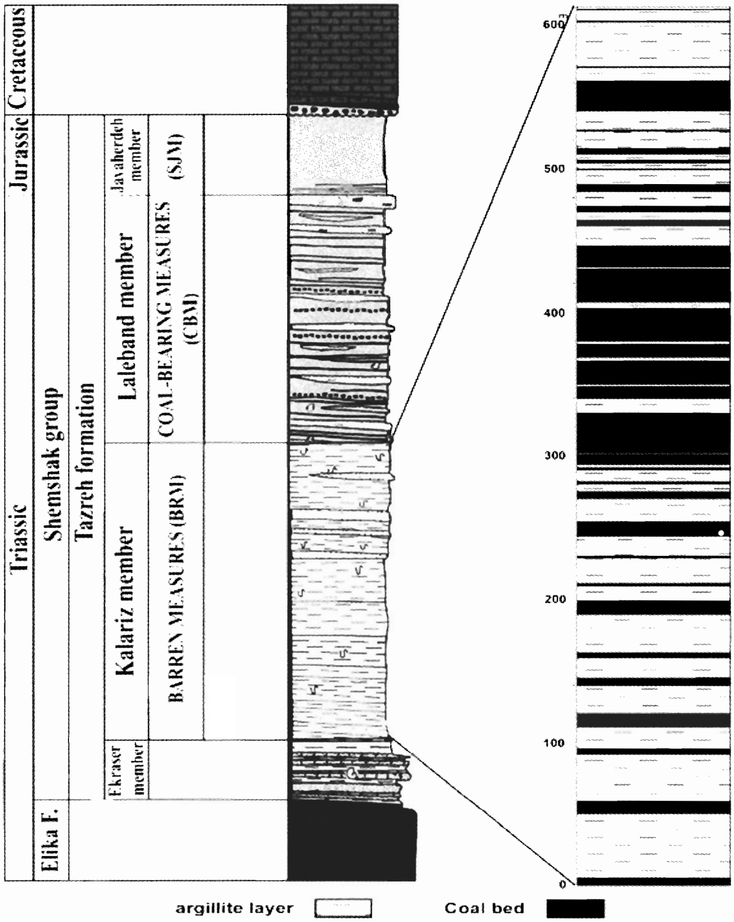

Fig. 3. The generalized stratigraphic sequence of the Galandrud coalfield.

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

Presence of magmatic activities due to tensional phase of previous Cimarian orogeny has triggered the coal seams adjacent to these magmatic mass to be metamorphosed into coke [12]. These activities are also the cause of hydrothermal metamorphism (often silication) of limestone in the region.

4.2. Characteristics of coals with tradional coal parameters

Analysis of 17 samples taken from coal beds of Galanderud indicates that moisture of this region's coals varies in the range of 0.88-1.37%, depending on different oxidation degrees of coals (Table 1). The ash-remains from coals are considered one of the main characteristics of coal. Zoubekov (1967) suggested that the colour and type of produced ash can indicate the type of maceral constituent of the coal. For instance, fusite maceral produce a compact ash with a brown or dark-grey colour. Presence of durite maceral leads to production of a powdery ash with colour ranging from bright-grey to white. Clarite leave a fine powder with reddish brown colour and ash from vitrite maceral has a bright-yellow colour [12].

The ash content of coals of Galanderud region, which mainly is in the form of grey compact particles, varies from 12.2-18.6%. Its high percentage can be associated with coals' formation environment. The coals forming in the marshy environment have high ash percentage due to pollution with clastic materials, (Thomas, 1992). As a whole, Galanderud coals have meltable ash, because of high percentage of ferroxide, calcium, and magnesium (40-60%) [2].

Table 1.

Geochemical properties of the Galandrud coals obtained from proximate [8].

Layer No.	Moisture (%)	Ash (%)	Volatila Matter (%)	Total Sulphur($\%_{wt}$)	Vitirnite Reflation($\%R_o$)
1	1.37	15.00	33.60	1.05	0.89
2	1.18	16.80	35.30	0.59	0.90
3	1.09	12.90	38.00	1.09	0.88
4	0.88	15.40	29.06	0.99	0.92
5	1.11	14.08	28.30	0.54	0.89
6	1.15	15.06	38.10	0.69	0.91
7	1.07	17.60	38.50	0.55	0.90
8	1.12	16.00	32.90	0.59	0.89
9	1.06	15.50	36.50	1.01	0.88
10	1.11	17.90	36.50	1.01	0.88
11	1.12	12.20	32.90	0.59	0.88
12	1.05	15.60	37.20	0.49	0.89
13	1.11	16.20	38.00	0.48	0.90
14	1.04	13.20	35.50	0.45	0.91
15	1.10	13.30	39.30	0.62	0.90
16	1.12	18.60	39.00	0.56	0.90
17	1.15	17.20	39.30	0.60	0.90

The volatile matters content of these coals varies from 28.3% to 39.3% that is generally increasing from the bottom layers towards the surface in some coal beds (Fig. 4). Due to performance of existing sub-faults in the region, the amount of volatile matters is showing an abrupt decrease (layers 4, 5, 8, 11& 14) or increase (layer 3) (Fig. 4). Basing on the amount of coals' volatile matters, according to ASTM (1991) classification, Galanderud coals is classified as a group of high volatile Bituminous B (>31%).

In Galanderud'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 [10]. Total sulphur amount of these coals in different coal beds range from 0.45 to 1.01 % of wt. Pyrite sulphur of coals is also very low so that pyrite mineral is only observable at some coal beds (for example layer 28) in the form of fine and dispersal particles with framboid texture (Fig. 5).

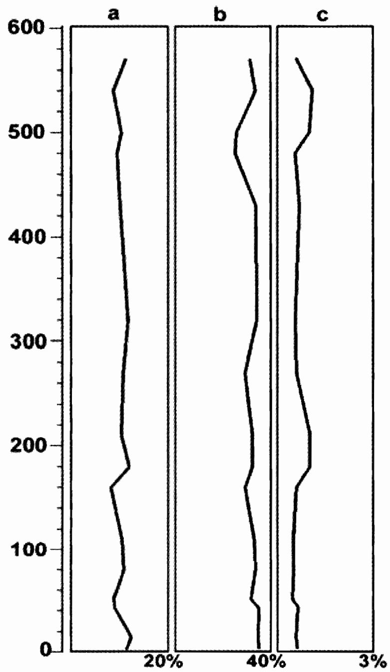

Fig. 4. Geochemical properties variation diagram: (**a**) ash (%), (**b**) volatile matters (%) and (**c**) total sulphur (%wt) of coal beds of the Galandrud coalfield.

Calorific value of Galanderud coals has been estimated between 7430 to 8880 kcal/kg. Rank of these coals is based on Russian classification, which is one of the most common classification methods for estimation of coal rank [6]. The rank is varying from gaseous degree (at surface layers) to greasy gaseous (at bottom layers) (Table 2). This trend of increasing rank of coal beds from surface to bottom is according to Hilt Law (1873): "In a vertical sequence of any locality in a coalfield the rank of the coal same rise with increasing depth." (Fig. 4).

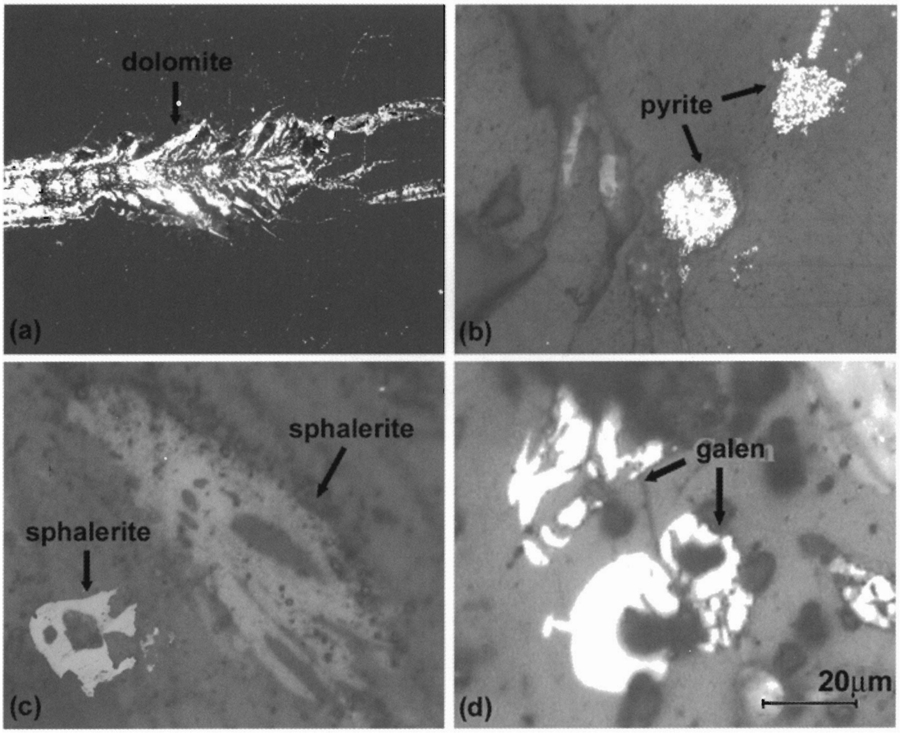

Fig. 5. Some selected microphotographs of minerals formed in Galandrud coals: (a) Dolomite that has filled into cracks. (b) Pyrite with framboid texture. (c) Sphalerite. (d) Galen.

Table 2.

Rank of the Galanderud coals is based on Russian classification method [6].

Russian classification	Name in Iran	Carbon (%)	Vitirnite Reflation(%R_o)	Vitirnite Reflation(%10R_a)
σ	Brown coal	76	0.43	58-66
D	Flaming	77	0.63	70-76
Γ	Gaseous coal	82	0.81	77-81
)-(	greasy coal	85	1.00	82-89
K	Metallurgical coal	89	1.32	90-97
Oc	Skinny coal	90	1.80	100-107
T	Thin coal	91	3.24	108-115
A	Anthracite	92	4.30	130-145

Generally, the coal is comprised of two mineral and organic parts. Study of thin and polished sections of coals and also XRD analysis in Galanderud by Goodarzi and colleagues (2006) demonstrates that mineral composition of these coals is formed mostly of dolomite (more than 90%), siderite, quartz minerals, and a little of kaolinite (clay mineral), sphalerite and galen (Fig. 5). Based on the study by Stasiuk et al. (2006) that determined the maceral constituent of Galanderud coals, vitrinite group (containing more than 30% of collotelinite) forms virtually half of the macerals in coals (47%) which are not unexpected given the fact that these coals are bituminite. Results of this analysis showed that macerals belonging to Inertinite group especially fusinite (25/25%) are in the second rank by more than 36%, and macerals belonging to liptinite group are forming only a few percentage of maceral constituent of organic part in Galanderud coals. Pores and gaps present in macerals are filled by silica, carbonate and pyrite [9] (Fig. 6).

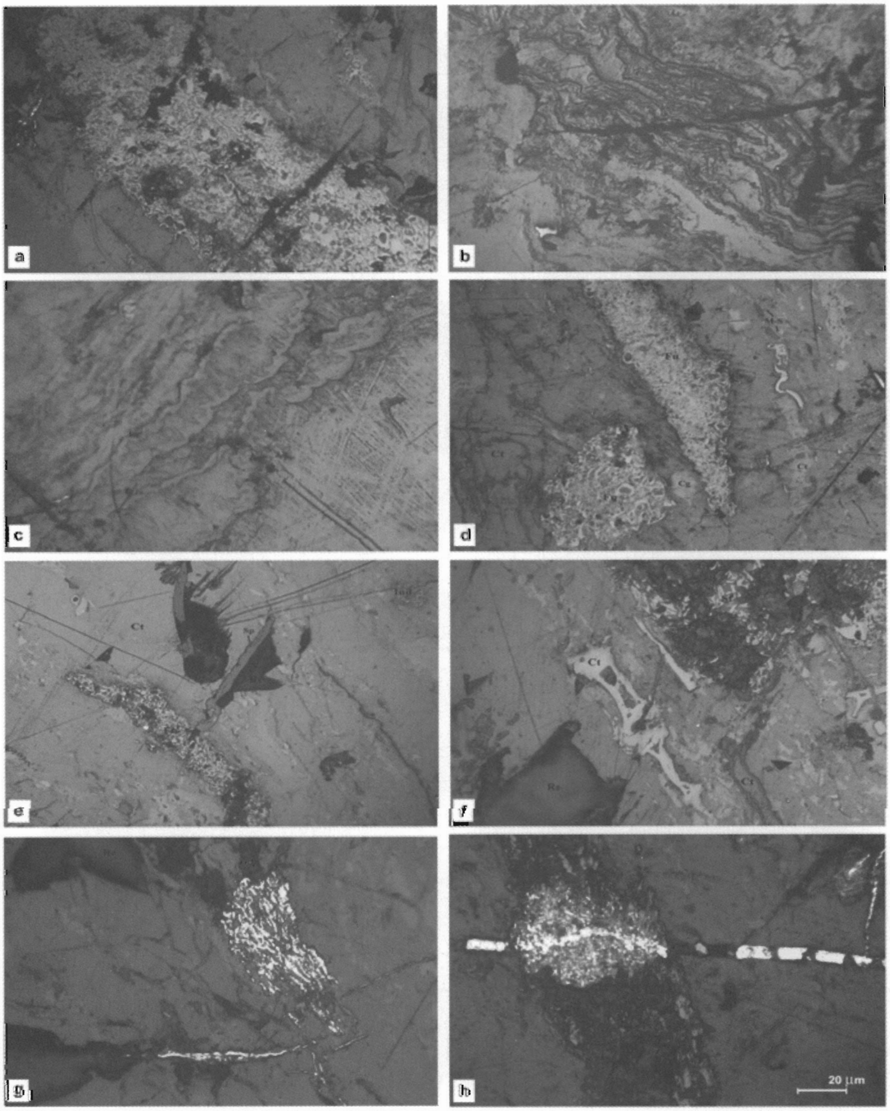

Fig. 6. Photographs of macerals in Galandrud coal: (a) Collotelinite and Fusinite. (b,c) Collotelinite. (d) Fusinite, Collotelinite,Corpogelinite and Micro-sporinite. (e) Fusinite band, Collodetrinite, Inertodetrinite, Micrinite, Resinite and Sporinite. (f) Semifusinite cell walls filled by clay minerals and calcite, Resinite, Cutinite, Macrinite into Collodetrinite. (g,h) Fusinite band that mineralized cell walls filled by framboid pyrite and fragments other macerals, pyrite mineral had filled crack chambers.

In our opinion, estimated values by Stasiuk and colleagues are not general for all 32 layers of Galanderud coal. We suggest that the fusinite maceral present within some coal beds of Galanderud region are far more than estimated amount, for the following reasons. First, in some coal seams (for example layer 26), coal powdered charcoal by coals is so high that makes their extraction more difficult in mine. Due to powderiness of fusinite [7] the strong powderization factor of coals can be associated with the presence of high percentage of fusinite maceral in these coals. Second, the type and colour of ash produced from these coals, which are in the form of grey compact particles, represent the predominance of fusinite maceral compared to other macerals. Third, since fusinite maceral is rich in carbon and developed from remains of charcoal [6], our study of thin and polish sections proves that charcoal is the main component of these coals in some coal beds. Charcoals in thin sections like opaque minerals are seen as black and woody materials (Vitrinite maceral) is visible in some points in the form of fragment or bands with bright red colour (Fig. 7).

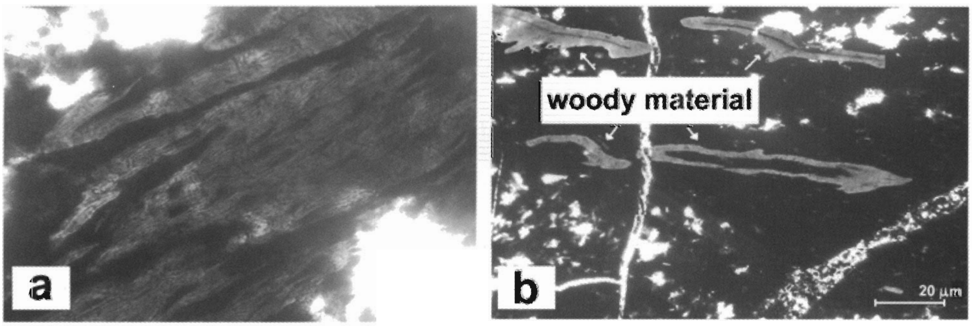

Fig. 7. Showing composition coals by thin section: (a) The thin red bands running horizontally across this view are thin shred of well-preserved woody materials. (b) Woody material and the black materials is either charcoal or opaque mineral matter.

4.3. Metamorphism of coals

In Mesozoic sediments of Iran, Metamorphism of deposited coals is remarkable in a wide spectrum and indicates great complexity. Rapid local changes of coals' metamorphism in a relatively short interval and irregularity between them shows complete lack of discipline, and this has caused researchers to present different views on metamorphism of different coalfields in Iran.

Most of the researchers such as Sinintichokov & Slender (1971-72), Losxmin (1975), Solovitskky et al (1997) have designated coals' metamorphism in Iran more than the variety of natural regional metamorphism. However, they have not rejected the idea that magma permeation or tectonic movements have locally caused the increase of metamorphic degree of coal seams [12]. Metamorphism degree of coals in Galanderud region of central Elburz has been investigated by method of vitrinite reflection (%R_o). The value of %R_o at different coal beds of this region is fluctuating between 0.88 and 1 (Fig. 4). Location of carbonaceous sediments of Galanderud in center of syncline and deep under ground with calorific gradient of about 25°c/km [3] has led to coals that are affected by regional metamorphism.

However, non-steadiness and bilateral changes of coal metamorphism in these coal beds indicate existence of another metamorphism in evolution course of metamorphism in Galanderud region. Effect of calorific metamorphism (tangential) on coal seams of Galanderud, due to none-adjacency of volcanic permeation matters (dyke and floods) to coal beds, is not far unexpected. Nevertheless, abrupt changes of coal metamorphism for some coal beds of Galanderud have made some researchers to consider involvement of friction metamorphism in this case.

The concept of friction metamorphism in coals of Iran was originally proposed by Cgernomazov (1969) and Alekseyeva (1972). They believed that tectonic movements and local faults' activity within carbonaceous sediments have caused metamorphism and change in carbonaceous degree of coals, in addition to replacing coal seams [11]. The existing tectonic pressure at central Elburz and activity of abundant faults in Galanderud region has led to replacement of the most coal beds. The tectonic pressure has caused severe fragmentation of coal seams due to increasing heat, in addition to locally increasing the metamorphism degree of these coals in layers. Such phenomenon is seen clearly at fourth layer of Galanderud region. Coals of this layer contain predominantly vitrinite maceral of kind (Collonite) with vitrinite reflection of 1 $\%R_o$ and of low volatile matters (29%). The existance of these characteristics in coals is indicators of friction metamorphism [12]).

5. Conclusion

Coals of the Galanderud region, located in central Elburz in northern Iran, which have been deposited in a fresh water Liminic sedimentary environment and with humus origin, are of Bituminuse B with high volatile matters (35%). In our study area, 32 coal beds have been detected 17 of which are workable. These coals have high ash and low sulphur content and their rank is increased from surface to bottom by reduction of volatile matters. Therefore, the type of coals is varying from gaseous to greasy gaseous. In regard to metamorphism of Galanderud coals, there are zonal metamorphism which is due to predominant tectonic pressure in the region and activity of the existing subfaults. In addition, friction metamorphism has occurred that in some layers caused a local increase in the rank of the coals.

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MƏRKƏZİ ƏLBURS REGİONUNUN KÖMÜR YATAQLARININ GEOLOJİ VƏ PETROQRAFİK XÜSUSİYYƏTLƏRİ (İRAN İSLAM RESPUBLİKASI)

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Məqalədə İranın şimalında yerləşən Mərkəzi Elburzun Gələndrud rayonunun daş kömürləri (0.80-0.83 R_o%) uzərində aparılmış tədqiqatların nəticələrinə baxılmışdır. Müəyyən edilmişdir ki, Üst Trias - alt Yura yaşı Şimşək formasiyasının daş kömür çöküntüləri 32 kömür layından təşkil olmuşdur. Bu kömürlər külün miqdarının (12.2-18.6%), uçucu komponentlərin (28.3-39.3%) və istilik vermə qabiliyyətinin (7430-8880 kcal/kg) nisbətən yüksək miqdarları ilə səciyyəvidirlər. Gələndrud rayonun kömürlərində kükürdün miqdarının aşağı (0.45-1.05 $\%_{wt}$) olması rayon kömürlərinin şirin su mühitində əmələ gəlməsini göstərir. Mineral kükürd yalnız bəzi kömürlü laylarda narın dənələr və səpələnmiş pirit formasında rast gəlir. Bu kömürlərin mineral tərkibi dolomitdən (80%-dən artıq), sideritdən, kvarsdən, sfaleritdən və galenitdən ibarətdir. Onların üzvi hissəsini təşkil edən inqredientlər əsasən vitrinit (kolotelinit) və inertinit (fuzinit) qrupundandırlar. Onlardakı boşluq və çatlar karbonatlarla və kvarsla dolmuşlar. Kömürlərdə uçucu komponentlərin miqdarı səthdən dərinkilərdə yerlışən laylara doğru tədricən azaldıqca, kömürlərin kömürləşmə dərəcəsi artır və kömürlər yağlı növlərindən qazlı növlərinə keçirlər. Gələndrud rayonun kömürlərinin kömürləşmə dərəcəsinin dəyişmə prosesinə, regional metamorfizmdən başqa tektonik hərəkətlər, çatlaşma və eroziya metamorfizmidə təsir edmişlər.