Classification of Coking Coals in C1 Seam of East-Parvadeh Coal Deposit, Central Iran Using Multifractal Modeling

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Abstract

The objective of this study is to identify the most suitable portions of the C1 coking coal seam in the North Block of the East-Parvadeh coal deposit (Central Iran), according to ash and sulfur values, using C-N fractal modeling. Based on the C-N log-log plots, different geochemical populations were evaluated based on their sulfur and ash content. They were then divided into five populations each according to their sulfur and ash percentages. The first sulfur containing population, located in the northern and western sections of the area, contains the best quality coking coal. The sulfur content ranges from 0-1.51%, known as "very low". Situated primarily in the western and northeastern sections of the North Block are two ash populations with ash values between 0 and 12.88%. Known as "very low" and "low", they are also of suitable quality for coking coal.

Keywords: *Concentration-Number (C-N) fractal modeling, ash, sulfur, East-Parvadeh coal deposit*

1. Introduction

Delineation of the portions of bituminous coal seams containing coking coal is essential for mine planning and equipment selection in coal mines. Ash and sulfur values are important factors in the selection of the appropriate coal portions considered for coke production. However, the materials are important for environmental control of coal mining [1]. Iranian coking coal reserves/resources are between 7-10 Gt. Most occurs in two main basins, the Alborz Basin located in northern Iran and the Central Basin located in central Iran. The Tabas Coalfield contains a high percentage of Iranian coking coal (3-4 Gt) used for metallurgical application [2, 3]. The spatial distribution of geochemical data is significant in the recognition of different mineralized zones. Conventional statistical methods which are based on quantities such as mean, median and standard deviation cannot always classify geochemical populations, e.g. ore mineralized zones or anomalies, because the methods are defined based on normal data distribution [4-7]. Fractal/multifractal modeling was established by Mandelbrot (1983) and has been widely used in the geosciences since the 1980s [4,7-16]. Cheng et al. (1994) and Cheng (1995) proposed concentration-area (C-A) and concentration-perimeter (C-P) fractal models in order to distinguish geochemical anomalies from the background and calculate elemental threshold values for various geochemical data [4, 17].

Other fractal models, such as power spectrum-area (S-A) by Cheng et al. (1999), concentration-distance (C–D) by Li et al. (2003), concentration-volume (C-V) by Afzal et al. (2011) and concentration-number (C–N) by Hassanpour and Afzal (2013) [12, 15, 18,19] have all been developed for and applied to geochemical and geophysical exploration. For this paper, C-N fractal modeling was used to isolate ash and sulfur populations based on drill core data from the C1 seam of the North Block of the East-Parvadeh coal deposit, Central Iran.

2. Geological Setting

The East-Parvadeh coal deposit is approximately 80 km south of the Tabas district, Central Iran (Fig. 1). The Tabas coalfield region is part of central Iran's structural zone which is divided into three different sub-zones, Parvadeh, Nayband and Mazinu [3,20].The Parvadeh area consists of six parts divided by major faults. The East-Parvadeh coal deposit (Fig. 1) is divided into the North and South Blocks by the Zenoughan fault. The North Block, according to dip, depth and structural effects of the coal seams, is superior to the South Block [20].The Nayband formation and Ghadir member of the coal bearing strata of the Tabas coalfield includes sediments of Upper Triassic and Middle Jurassic age. Rock types include siltstone, sandstone, shale, sandy siltstone and small amounts of limestone and ash coal. Coal seams in the Parvadeh district are named A, B , C , D , E and F. Based on quality and quantity, seams B and C are considered minable, particularly C1 and B2 [3].

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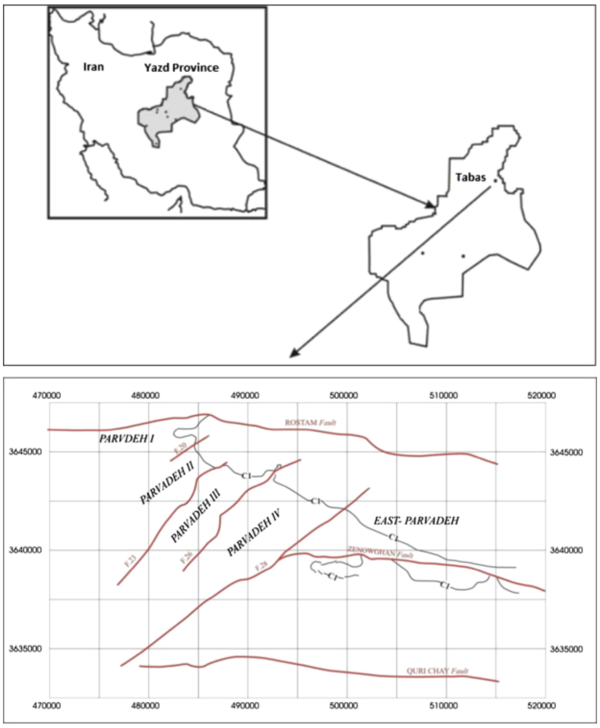


Fig.1: Location of Parvadeh and East-Parvadeh deposits in Tabas coalfield.

3. Methodology

The number-size (N-S) fractal model, originally proposed by Mandelbrot (1983), can be used to classify different geochemical populations without the need for pre-processing data [8]. The model reveals that there is a relationship between desirable attributes (e.g., low sulfur and ash values in this paper) and their cumulative number of samples. Based on this, Agterberg (1995) proposed a multifractal model, called size-grade, for determination of the spatial distributions of giant and super-giant mineral deposits [21]. Monecke et al. (2005) used the N-S fractal model to characterize element enrichments associated with metasomatic processes during the formation of hydrothermal ores in the massive Waterloo sulfide deposit, Australia [22, 23]. A power-law frequency model was proposed to describe the N-S relationship according to the frequency distribution of element concentrations and cumulative number of samples with those attributes [14, 23-26]. Hassanpour and Afzal (2013) intended the elemental C-N model to be a branch of the N-S model used to outline geochemical background and anomaly threshold values [19]. The model has the following form:

$$N(\geq\rho) \propto \rho^{-\beta} \quad (1)$$

$N(\geq\rho)$ denotes the sample number with concentration values greater than the ρ value, ρ is the element concentration and β is the fractal dimension. In this model, primary process and evaluation was not done on the geochemical data [19, 27].

4. Discussion

For this study, 73 samples were collected from 87 boreholes in the C1 coal seam. Chemical analysis was carried out to estimate the sulfur and ash content of these samples. The resource database consists of information based on the interpretation of surface and sub-surface data including collar, orientation, stratigraphy and values for sulfur and ash. Selection of the project dimensions for computerized 3D seam modeling was done according to the area, borehole coordinates (collar) and project dimensions, calculated as 14,500m, 5,500m and 820m for X, Y and Z respectively. The 3D stratigraphic, sulfur and ash distribution models for the C1 seam were produced using the RockWorks v.15 software package (Fig. 2). The Inverse Distance Squared (IDS) estimation method was used for creating sulfur and ash distribution models.

C-N log-log plots for ash and sulfur in the C1seam were generated, as depicted in Fig. 3. The breakpoints between straight-line segments in these log-log plots indicate threshold values and separate the populations containing different sulfur and ash values in the C1 seam (Fig. 3). Based on the C–N log-log plots, there are five different geochemical populations for both sulfur and ash (Tables 1 and 2). The first sulfur containing population, located in the central and eastern parts of the area, has sulfur values lower than 1.51% known as “very low”. This is the best population for coking coal according to Russian standards (Fig. 4 and Table 3) [3]. Other populations considered appropriate according to sulfur content are “low sulfur” populations. They contain sulfur values from 1.51%-2.51% (Table 1). Populations with the lowest quality for coking coal according to sulfur content contain sulfur values higher than 3.46% (Fig. 4).

The first ash population, located in the western parts of the area, contains the best quality coking coal. It shows values lower than 6.3% known as “very low” (Fig. 5 and Table 2). The second population is the largest and extends from east to west as depicted in Fig. 5. It shows values between 6.3% and 12.88%, known as “low” and is considered acceptable for coking coal based on Russian standards (Table 3) [3]. The third ash population shows values ranging from 12.88%–28.18% entitled “moderate”. “High” ash populations contain 28.18-41.68 % ash while the last population, “very high”, contains ash values higher than 48.68% called “ash coal” or “argillic coal” based on Russian standards.

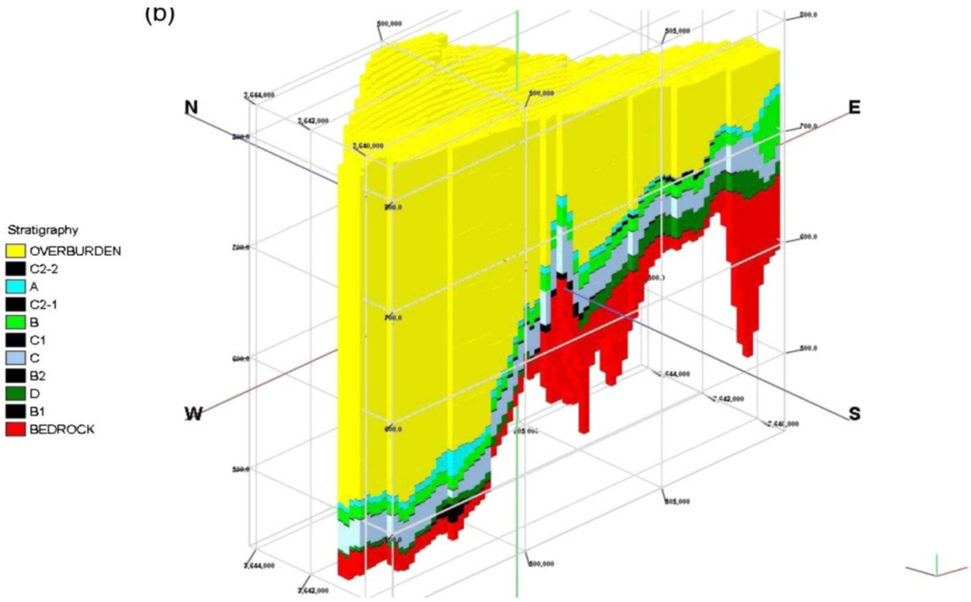


Fig. 2.Stratigraphic model for North block of East-Parvadeh coal deposit [28]

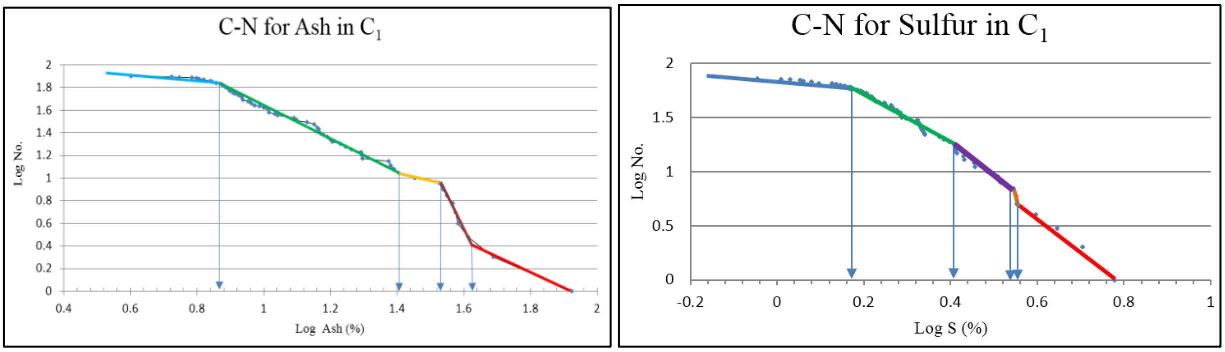
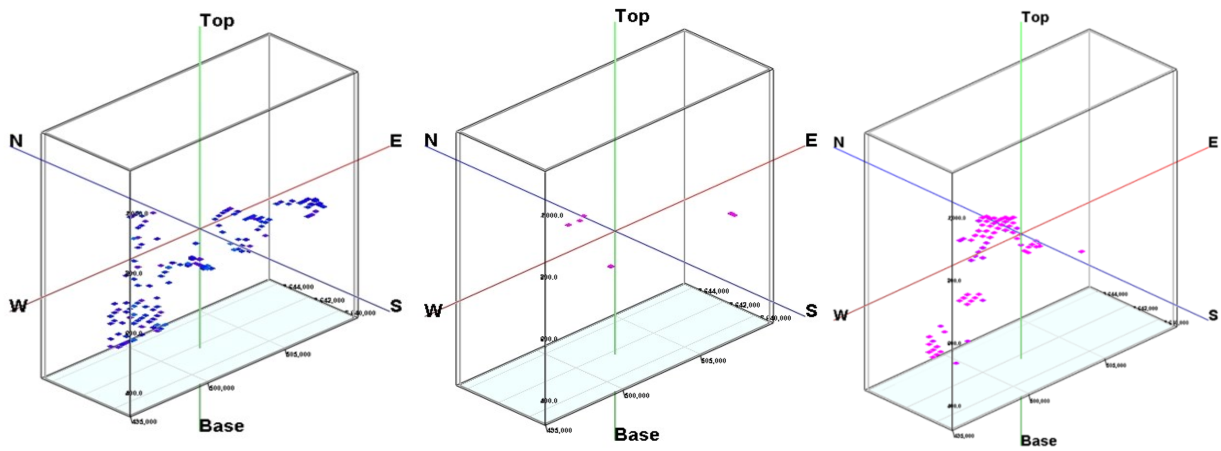


Fig.3: C-N log-log plots for sulfur and ash in the C_1 seam North Block of East-Parvadeh.



(a) (b) (c)

Fig. 4: (a) “very low” sulfur (≤ 1.51%), (b) non-proper (> 1.51%) and (c) “low” sulfur (1.51% < S ≤ 2.51%) populations obtained by C-N fractal modeling based on sulfur values of C1 seam.

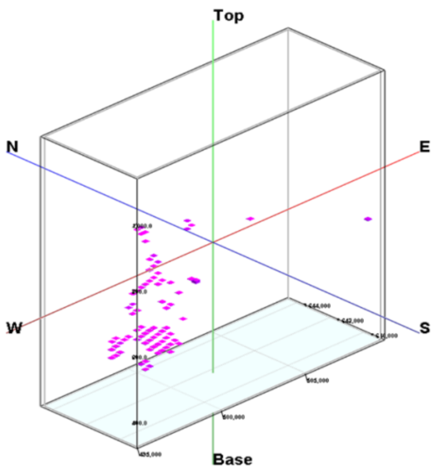


Fig. 5: Acceptable (≤ 12.88%) populations based on sulfur values in C_1seam obtained by C-N fractal modeling.

Comparison of results obtained using C-N fractal modeling for sulfur and ash values and available geological information reveals that there is a close correlation between results derived via multifractal models and geological particulars. Based on the geological indications, there are some pyritic veins in the eastern and southern parts of the C1 coal seam. This correlates to high sulfur portions derived by the C-N fractal model in the eastern and southern parts of the seam. Furthermore, comparison of the results obtained using C-N Fractal modeling and the Russian standards for coking coal show similar thresholds for ash and sulfur (Tables 1 and 2).

Table 1: Populations for sulfur in C_1 seam based on C-N fractal model

Category	Very low	Low	Moderate	High	Very high
Sulfur (%)	≤1.51	1.51-2.51	2.51-3.46	3.46-3.63	>3.63

Table 2: Populations for ash in C_1 seam based on C-N fractal model

Category	Very low	Low	Moderate	High	Very high
Ash (%)	≤6.30	6.30-12.88	12.88-28.18	28.18-41.68	>41.68

Table 3: Russian standards for coking coal (10583-72) and (7059-75) [29]

Category	Very low Ash	Low Ash	Medium Ash	Relatively High Ash	High Ash	very high Ash
Ash (%)	0-10	10-15	15-25	25-31	31-40	> 40
Category	Very low Sulfur	Low Sulfur	Medium Sulfur	Relatively High Sulfur	High Sulfur	very high Sulfur
Sulfur (%)	0-1	1-1.5	1.5-2.5	2.5-3.5	3.5-5	> 5

5. Conclusions

Based on C-N multifractal modeling, there are five populations for both sulfur and ash in the C1 seam of the North Block. The first populations for sulfur and ash data, located in the central and eastern parts of the area, have the highest quality coking coal ("very low", <1.51 % sulfur and "very low", <6.3% ash). Populations containing "low" values of sulfur (<2.51%) and ash (<12.88%) are located primarily in the northern and western parts of the North Block. Low quality coals with "high" and "very high" ash content (>41.68%) called "ash coal", along with "high" and "very high" populations for sulfur (> 3.46%) located in the eastern part of the area contain several pyrite veins validated by C-N fractal modeling.

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