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Lignite resource estimations and seam modeling of Thar Field, Pakistan

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ABSTRACT

Thar lignite field in Pakistan contains more than 175 billion tons thus far not exploited. To date, the coalfield has been divided into 12 exploration blocks and each block is studied and investigated separately by different agencies. As a result of exploration programs, a large exploration database containing geological and coal quality information is constructed, but geostatistical studies regarding to quantify entire Thar lignite resources is not available yet. This paper aims to generate 3D solid model of main Thar seam and to produce spatial distribution maps for various coal quality attributes by geostatistical method, ordinary kriging. 3D seam model has a volume of 17.71 billion m^3. The resulting spatial map of ash content shows structured distribution and LCV map shows fair agreement with ash map except in block VI where high and low values of ash and LCV occur in close proximity. The moisture distribution reveals higher values in northern and southern parts whereas the central portion possesses lower moisture values. The sulfur content shows homogenous distribution with some higher sulfur patches at places. The kriging variance maps are generated to delineate areas of higher uncertainty. These maps could be helpful to devise further exploration programs. Blocks were checked on the basis of global averages and swath plot comparison.

1. Introduction

At present, Pakistan is facing serious energy crisis. Severe shortage of electricity has badly affected the industrial and social activities. Pakistan is spending over US$ 14.5 billion on imports of crude oil, petroleum products, coal, LPG etc. to fulfill energy requirements (Hydrocarbon Development Institute of Pakistan, (Hydrocarbon Development Institute of Pakistan (HDIP, 2012)). Coal is a cheap source of energy and widely used throughout the world for power generation, cement and other process industry. The world electricity generation by fuel reveals that coal is the highest contributor in electricity generation and demand of coal will remain dominant in the worldwide electricity generation (Energy Information Administration, USA (EIA, 2011)). The installed electricity generation capacity of Pakistan is about 22.263 GW with 29.9% hydroelectric, 35.2% oil, 29% natural gas, 5.8% nuclear/imported and only 0.1% coal, as shown in Fig. 1 (HDIP, 2012). Share of coal in electricity generation in Pakistan is very negligible as compared to world average.

Pakistan possesses the 7th largest lignite resource in the world with nearly 200 billion tons of coal, mainly concentrated in Thar region having more than 175 billion tons of lignite resources (Singh et al., 2011). Thar lignite field, the largest coal resource of Pakistan, is located in the eastern part of Sindh Province (shown in Fig. 2). Thar coalfield covers an area of approximately 9000 km^2 and number of lignite seams lie at depths between 130 and 250 m. Cumulative seam thickness varies between 1.45 m and 42.6 m and the maximum thickness of an individual seam is 28.6 m (Pathan et al., 2013).

The Thar lignite was fortuitously discovered by British Overseas Development Agency (BODA) and Sindh Arid Zone Development Authority (SAZDA) during drilling for water wells near the village of Khario Ghulam Shah, Tharparkar, in 1988 (Fassett and Durrani, 1994). Further exploration work was conducted by Geological Survey of Pakistan (GSP) and United States Geological Survey (USGS) under Coal Resources Exploration & Assessment Program (COALREAP) from 1989 to 1994. In this exploration program, total 21 boreholes were sunk at an average spacing of 20 km to define the extent of coal occurrence (Thomas et al., 1994). Total hypothetical lignite resources were estimated at 175.506 billion tons. Since then 12 exploration blocks have been investigated separately by various agencies viz: GSP, Shenhua (China), Rheinbraun(Germany), Sindh-Engro(SECMC), Deep Rock Drilling (DRD) from 1994 to 2012. As a result of these exploration programs, a large exploration data including geological and coal quality information, is available; however no resource modeling study has been conducted to quantify entire Thar lignite resources using geostatistical modeling.

Several research studies on coal resource estimation and seam modeling have been carried out. Olea et al., 2011 combined different geostatistical methods for quantitative characterization for evaluating

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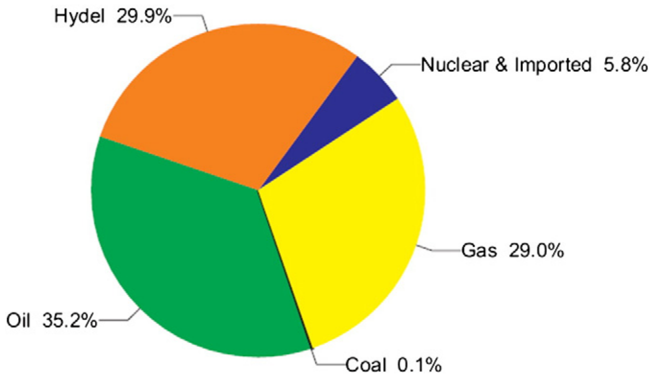

Fig. 1. Pakistan's electricity generation by fuel, 2011–12 (HDIP, 2012).

the uncertainty and indicated that distance to the neighboring drill hole is more or less completely dissimilar to the uncertainty, which demonstrate the deficiency of distance-based resource estimation approach. Hohn and Britton (2012) also demonstrated significance of geostatistical estimation over distance-based classification method. Tercan and Karayigit (2001) also estimated lignite reserves in Kalburcayiri field, Kangal basin, Sivas, Turkey using global estimation variance (GEV) approach. Pardo-Iguzquiza et al. (2013) assessed the risk associated with lignite reserves estimations at North-western Spain using semi-variograms and conditional simulation. Geostatistical modeling was conducted for quantification of error associated with reserves estimation at Jharia coalfield, India. The uncertainty maps were generated using kriging variances and areas of high uncertainty were identified for additional sampling for precise estimation (Saikia and Sarkar, 2013).

Hindistan et al. (2010) conducted case study on dilution problem at an underground coal mine in Turkey. The mean calorific values of the blocks inside the production panels were estimated using ordinary kriging to devise short term mine plan. Tercan et al. (2013) conducted thorough study at Eynez–Soma and Ömerler–Tunçbilek coal fields, Turkey for seam modeling and estimation of lower calorific value. The study sites were subjected to heavy tectonic movements and erratic coal quality. Falivene et al. (2014) carried out three-dimensional coal facies interpolations and simulations in a heterogeneous coal zone in the As Pontes Basin (North Western Spain) to forecast coal resources and reserves. This study ascertained that due to interpolation smoothing, the three-dimensional facies interpolation methods tend to overestimate coal resources and reserves whereas facies simulation methods yield similar resource predictions than conventional thickness map approximations. Vasquez and Nieto (2004) estimated calorific value and ash by weighting kriging estimation variances.

Ertunc et al. (2013) estimated the lower calorific value, ash content, and moisture content of lignite deposit subjected to severe tectonic activity, by using covariance matching constrained kriging and ordinary kriging. It is found that covariance matching constrained kriging replicates the spatial variability better than ordinary kriging. Heriawan and Koike (2008a) and Heriawan and Koike (2008b) estimate thickness, ash, sulfur and calorific value in a multiple seam environment at East Kalimantan (Borneo, Indonesia) by means of ordinary kriging, cokriging and factorial Kriging.

This paper aims to estimate various coal quality parameters using ordinary kriging technique that provides improved estimates and associated errors by means of kriging variances.

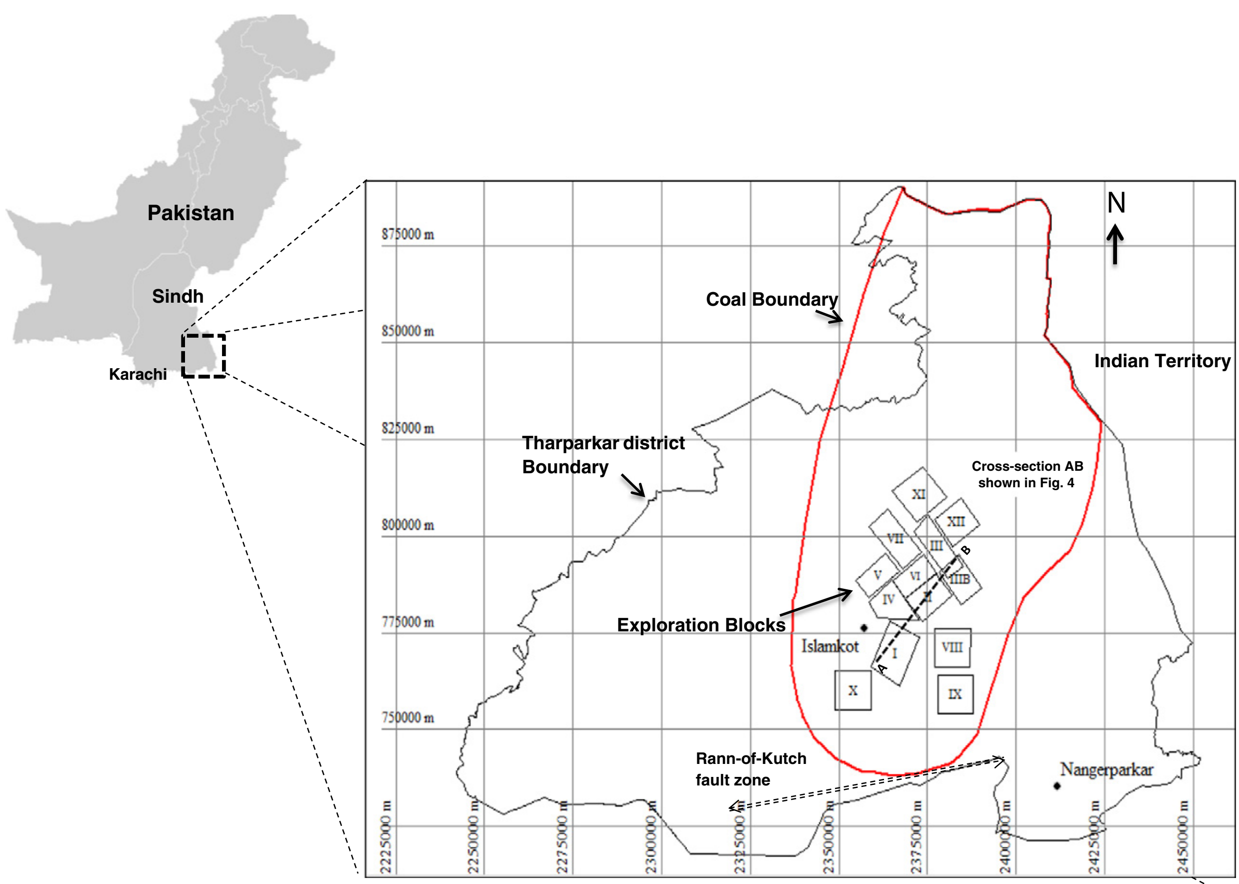

Fig. 2. Location map of Thar Lignite Field, Pakistan.