Fuel 177 (2016) 279–287

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Estimation of ash, moisture content and detection of coal lithofacies from well logs using regression and artificial neural network modelling

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HIGHLIGHTS

- Hierarchical Cluster Analysis (HCA) is applied for isolation of coal bands.
- Multiple regression models are proposed for prediction of coal proximate parameters.
- The proximate results are validated with the laboratory data.

ARTICLE INFO

Article history:
Received 29 August 2015
Received in revised form 29 February 2016
Accepted 1 March 2016
Available online 16 March 2016

Keywords:
Coal
Hierarchical clustering
Neural network
Regression
Proximate parameter
Korba coalfield

ABSTRACT

Coal core samples and well log data of five exploratory wells of Korba Coalfield (CF), India have been used for prediction of coal facies. The Indian non-coking coal lithofacies are generally classified by analyzing the variation of the geophysical log parameters or by defining the ranges of various proximate parameters (mainly ash % and moisture %) obtained from coal core samples. The objective is to classify each layer as coal, shaly coal and shale depending upon the content of ash % and moisture % of the corresponding layer in coaly horizon. Hierarchical Cluster Analysis (HCA) is applied to classify the non-coal horizons and bands of identified coal seams of each well under the study area based on geophysical log responses: natural gamma ray (NG), high resolution density (HRD) and single point resistance (SPR). Hierarchical clustering separates the zones in a particular coal seam from five wells using the nature of the curve. These zones/clusters are further identified as coal, shaly coal, shale in three wells using regression and multilayer feed forward neural network. The log responses and coal core analyzed proximate parameters of these isolated bands/zones in two wells are used for establishing linear regression and neural network models. The observation shows very satisfactory fit ($R^2 = 0.84$) between ash content and HRD and poor R^2(<0.41) between moisture content and log responses. The MLFN model is based on study of two wells using NG, HRD and SPR log responses as inputs and coal proximate parameters, namely, ash and moisture content as outputs to classify the coal lithofacies. The bands within a coal seam are classified on the basis of the ash and moisture content while training as well as the validation of the model. These linear and MLFN models are used to determine the ash % and moisture % in the remaining three testing wells. MLFN predicted results are more closely to the laboratory analyzed proximate parameters as compared to the results obtained from regression modelling.

1. Introduction

The interpretation of coal and non-coal lithofacies from well logs acts as a significant interpretation tool since core and sidewall samples are not usually available. Gas content of coal seams is determined based on several parameters including vitrinite reflectance, maceral content, maturity, coal quality and depth [34]. The quality of coal and its rank are determined by the content of carbon, ash, moisture and volatile matter [34]. The quality of coal and its properties generally vary from one coalfield to another [17]. Chatterjee and Paul [7] had discussed the variation of density (1.28 gm/cc to 1.55 gm/cc), gamma ray (20–50 cps) and resistivity (500–1200 ohm-m) values of coal in Jharia coalfield. The density, gamma ray and resistivity values of Manuguru coal of Pranhita–Godavari Valley, Andhra Pradesh ranges from 1.40 to 1.55 g/cc, 20–50 cps and 500–600 ohm m respectively [3]. It is observed that the range for coal density in Bishrampur coalfield varies from 1.28

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http://dx.doi.org/10.1016/j.fuel.2016.03.001
0016-2361/

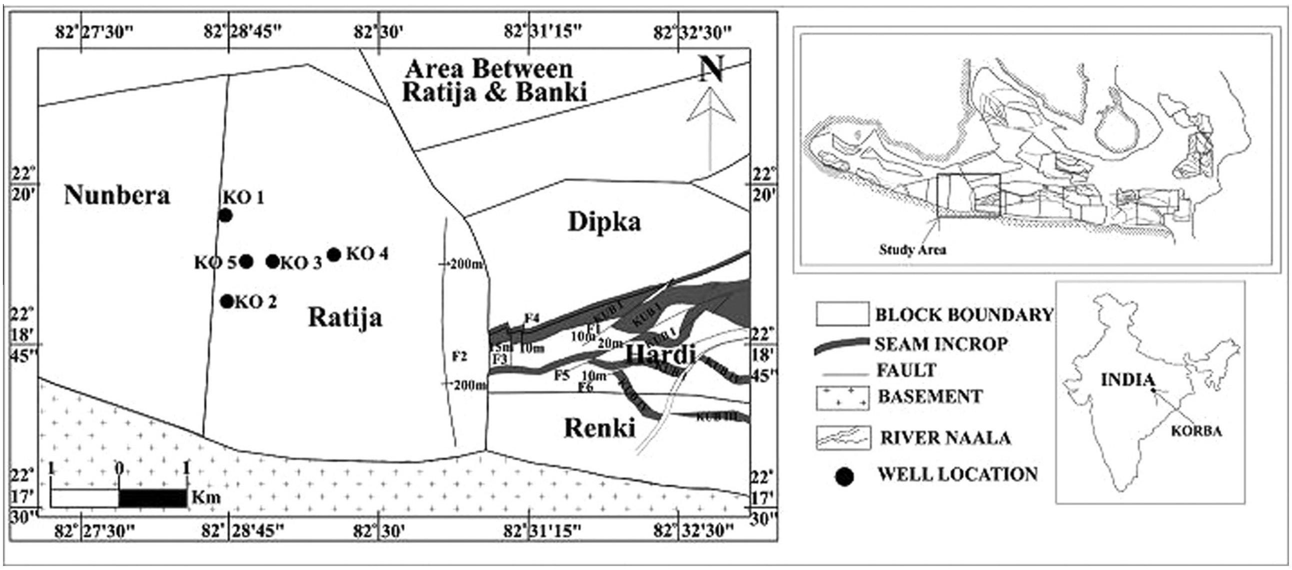

Fig. 1. Location of wells under the study area of Korba coalfield. Inset: The location of Korba in India.

Table 1
Generalised stratigraphic sequence of Korba coalfield (after [25]).

Age	Formation	Thickness (m)	Lithology
Recent	Alluvium	0.00–20	Soil and sub-soil
Lower triassic to upper permian	Kamthi	>200	Coarse ferruginous sandstones, pebbly sandstone and conglomerate
Lower permian	Upper Barakar	>300	Sandstones, shales, carb-shales and coal seams
	Middle Barakar	>200	Sandstones of varied grain sizes, shales and carb-shales with thick coal seams (like Kor V & Kor VI)
	Lower Barakar	>300	Predominantly coarse grained to pebbly sannstones with thin banded inferior quality coal
	Karharbari	>150	Coarse grained to pebbly sandstone with good quality of coal seams (Ghordewa group of seams)
	Talchir	>250	Fine grained compact sandstones, tillite and greenish shales.
Archean	Non-conformity		Granite, gneisses, etc.

to 2.05 g/cc [15]. The cut-off ranges of the concerned geophysical log parameters are observed to vary in different Indian coalfields for same lithofacies. Schmitt et al. [32] introduced classification of organic mud-rocks, coal and siliciclastic by using neural network from the well logs.

The physical properties of coal like natural radioactivity, single point resistance, electrical conductivity, density, transit travel time, neutron porosity are commonly measured through geophysical logging [24,6]. These are used for determining the type of coal as well as for quantifying coal proximate parameters through laboratory analyses [7,15]. Many researchers have developed several approaches such as statistical [5,31], fuzzy logic [35,29,21,15] and neural network [2,27,4,28,30,22,26] for estimation of coal proximate parameters and lithofacies identification.

The Ratija block of Korba Coalfield (CF) shown in Fig. 1 is under the initial stage of exploration. The coal seams including Upper Barakar and Lower Barakar Seams of Korba CF are of highly banded. As noticed from geophysical log and drilling data, most of the seams in Upper and Lower Barakar series include coal, shaly coal and shaly layers of varying thickness.

Generally for classifying the lithofacies within and beyond a coal seam of Indian Non-Coking Coalfields, only two of the laboratory proximate parameters such as ash and moisture content are essential and available for wells under study in Korba CF, Chhattisgarh, India. The lithofacies within coal horizons are classified into coal, shaly coal, carbonaceous shale and shale on the basis of sum of ash and moisture percentages of the received coal core (e.g. [8,3,23]). Thus, for extracting the lithofacies from the core samples, the two proximate parameters namely; ash and moisture content are required for each band. The entire set of four proximate parameters (ash, moisture, volatile matter and fixed carbon) is usually determined for the whole seam to decide the grade of the entire seam packet whereas the layer by layer lithofacies within each seam is governed by the corresponding sum of ash % and moisture % determined in the laboratory.

Therefore, the objective of this paper is firstly to isolate the layers/zones using hierarchical clustering analysis (HCA), secondly estimation of ash and moisture content band by band from regression and neural network modelling and finally prediction of coal lithofacies based on predefined cut-off from laboratory analyzed proximate data. Our study is focusing on separation of coal bands occurring at depths from 32 to 198 m from five wells using hierarchical clustering analysis (HCA) and development of regression as well as multilayer feed forward neural network (MLFN) for identification of clustered zone in terms of coal, shaly coal and shale lithofacies. For application of HCA and development of MLFN code in matrix laboratory (MATLAB), Korba CF located at Chhattisgarh State, India (Fig. 1) is chosen for band by band zonation from individual coal seam and detection of coal facies through MLFN modelling.

2. Study area

The Korba CF is nearly 4.8 km wide and 64 km long, located in the south central part of the Son–Mahanadi valley, Chhattisgarh