Application of Multiple-point Statistics and Image Logging Data in Modelling Coal Cleats Distribution

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PROJECT: UNDERSTANDING FAULTS AND FRACTURES IN THE SURAT BASIN

ABSTRACT

Coal has a complex porosity system that ranges from molecular to macroscopic pore sizes, the latter of which are commonly known as fractures. The orthogonal coal fractures or cleats contribute directly to coal permeability under variable stress conditions, and are the main conduits for gas and water flow in coal. In modelling and reservoir simulation, they are described by distributions referred to as Discrete Fracture Network models (DFN), and used to analyse near-wellbore coal properties, coal seam gas production, and well testing performance. This study presents a workflow to build a grid based DFN near the wellbore using the multi-point facies simulation (MPS) method. Core from three wells were measured for face and butt cleats spacing. An image log from one well was interpreted for cleats azimuth which was used in MPS as hard data. Firstly, we coded a program to generate cleats distribution based on the cleat spacing observed in core. Then the generated cleats were imported into Petrel to be used as the training image. We then built a 2D grid with cells number of 1000×1000 and grid size of 1 mm in x- and y- direction which is used in MPS modelling. Finally, ten realisations of cleats distribution near the wellbore were generated. Results show that this presented workflow is efficient in modelling cleats distribution by integrating image logs interpretations and core observed cleats.

INTRODUCTION

Coal has a complex porous system ranging from micro-, meso- and macro- pores, to visible fractures (butt and face cleats, joints and fractures; Laubach et al. 1998). Butt cleats and orthogonal face cleats, which contribute to the coal permeability, are the main conduits for gas and water flow in coal. After stress magnitude, the permeability is strongly dependent on the cleats spacing, geometry, orientation to stress, aperture size, connectivity, degree of mineralisation and topology (Close and Mavor, 1991; Laubach et al. 1998; Zhou and Yao, 2014; Jing et al. 2016). Discrete fracture models (DFM) or discrete fracture network (DFN) models are commonly used to analyse coal permeability and fluid flow (Gong et al. 2014). Zhou and Yao (2014) studied the effect of cleats aperture and spacing on coal permeability by building 2D cleat models. Gao et al. (2014) analysed the strength and deformability of coal based on $(2m)^3$ DFN models with bedding planes, face cleats and butt cleats. Jing et al. (2016) built DFNs for coal cleats based on micro-computed tomography imaging (µCT) and then using a Monte Carlo method to assign to the remaining reservoir. This latter point is the problem, as the borehole only confidently intersects the small scale cleat network, and the larger scale joints and faults are under represented.

This study presents a workflow to build a grid based DFN near wellbore using multi-point facies simulation (MPS, a pixel-based sequential simulation algorithm; Strebelle, 2002; Strebelle and Journel, 2001; Rezaee et al. 2015) method and image log data which has a high resolution to 5 mm but much smaller fractures can be imaged if there is a sufficient electrical contrast with the background (Weatherford, 2013).

Core from three wells, A, B and C shown in Figure 1 were measured for face and butt cleats spacing (55 points from well A, 138 from well B and 69 from well C). Image logging data from well D was used to interpret cleats, faults and fractures.

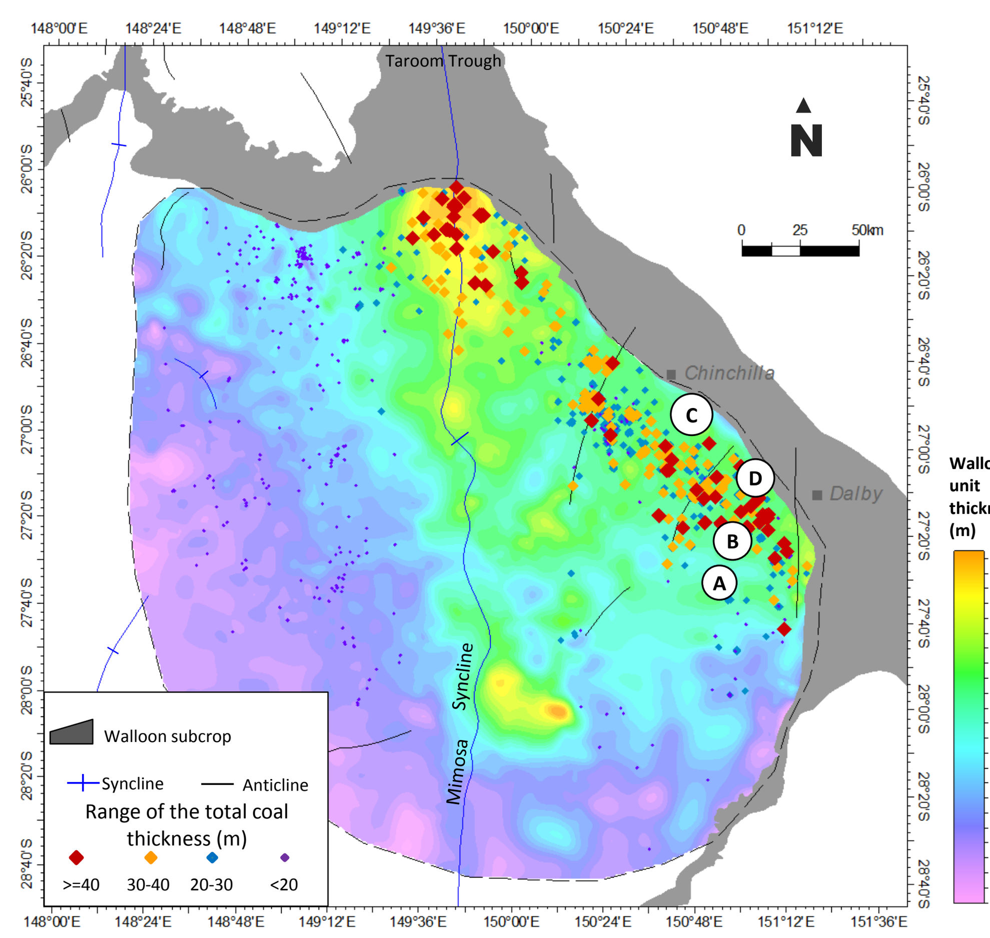

Fig. 1. Location of wells for this study in the Surat Basin

METHODOLOGY

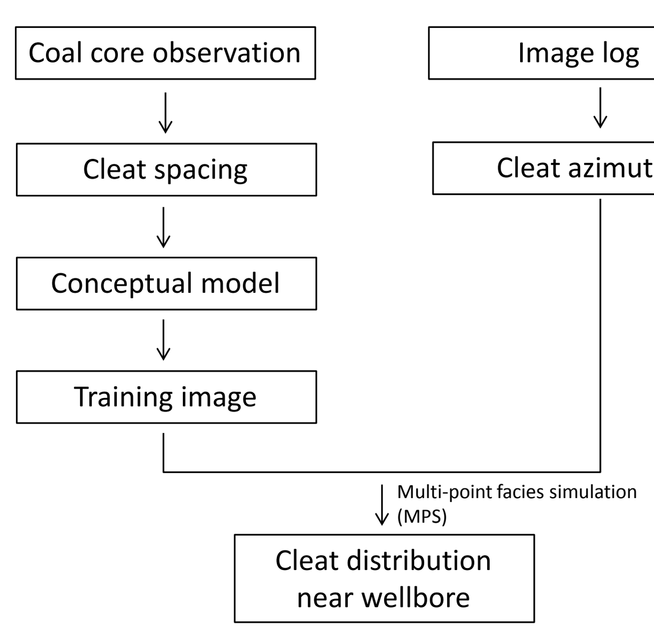

Fig. 2. Workflow for cleats modelling by MPS used in this study.

MPS is capable of producing models with more geological complexity than sequential indicator simulation and it is easier during conditioning to honour hard data than objective modelling. It is more commonly used for sedimentary facies modelling (Strebelle, 2002) but Zhang et al. (2006) used a continuous MPS in modelling the porosity distribution for a carbonate reservoir. MPS was also used to generate facies and fracture distribution based on the pattern statistics inferred from some training images (Erzeybek et al. 2012). The training image is used to explain the neighbourhood relationship of facies by creating patterns which is a prior distribution function (pdf; Petrel, 2014). During the pattern creation, multi-grids (Gómez-Hernández, 1991) are used to describe both small and large scale structures as short and long variogram ranges using the two-point geostatistics (Okabe and Blunt, 2005).

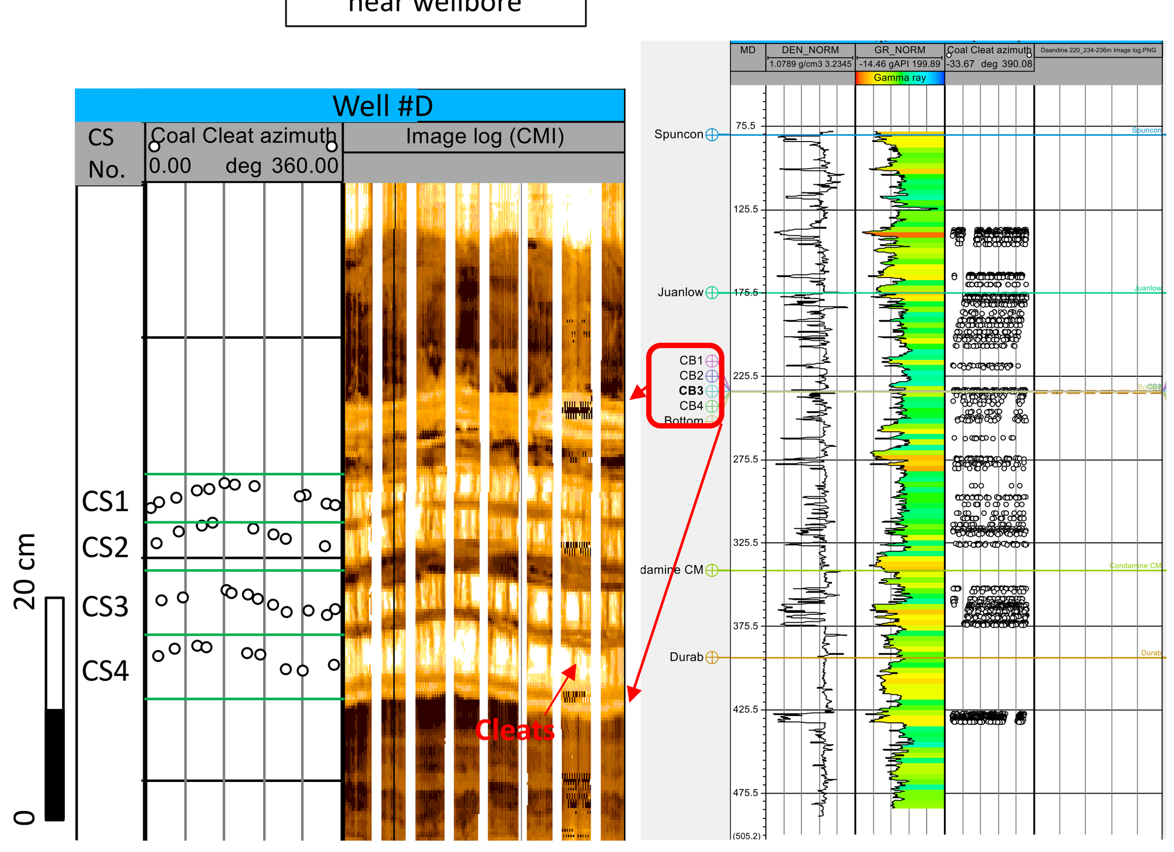

Fig. 3. Interpreted coal cleats azimuth for four thin coal seams. Thicknesses of CS1 to CS4 are 5, 6, 5 and 6 cm, respectively.

Compact Microimager (CMI; Weatherford, 2013) from well #D was interpreted for coal cleats azimuth and strike azimuth for conductive fractures and faults. Results show that the strikes azimuth for conductive fractures and faults are nearly along west-east direction which was assumed as the strike for face cleats because it's difficult to identify the orientation of face cleats from image log.

RESULTS

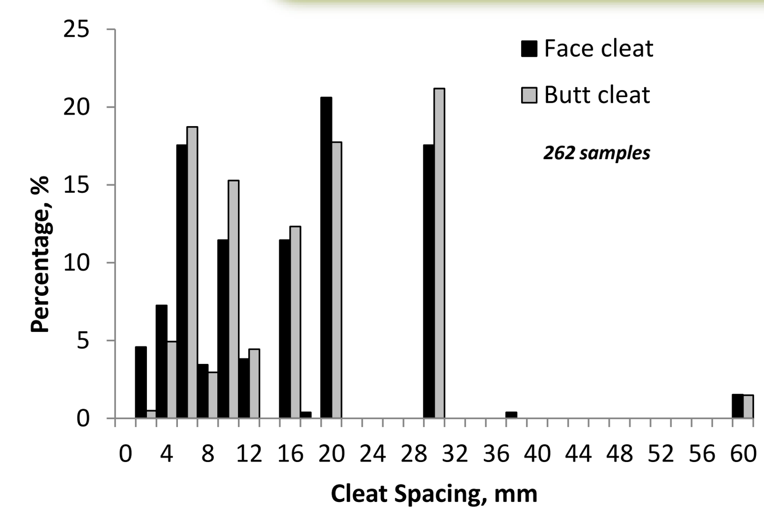

Fig. 4. Histogram of coal cleat spacing from boreholes A, B, and C which were shown in Fig. 1.

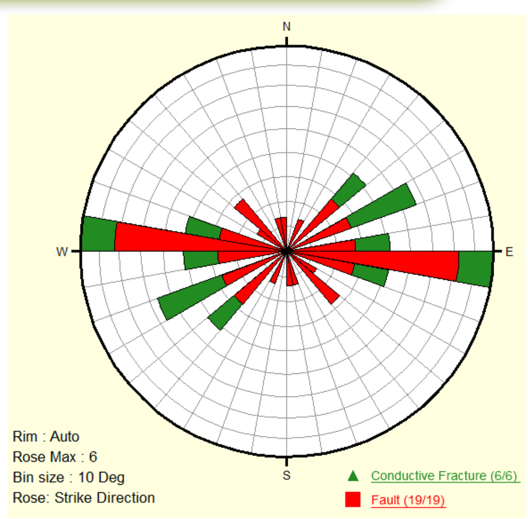

Fig. 5. Strikes for conductive fracture and fault which was assumed as the azimuth of face cleats

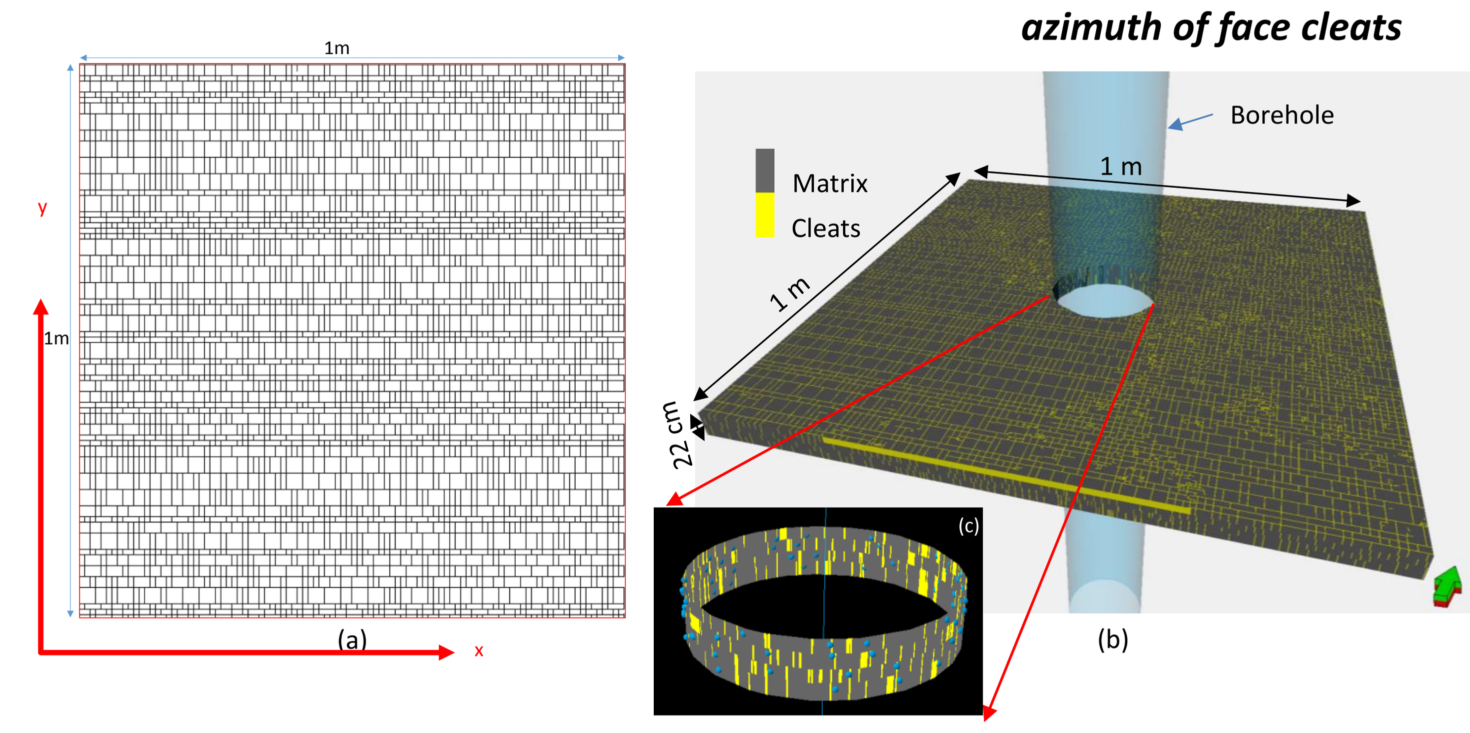

Fig. 6. A training image (a) and one realisation of coal cleats distribution near wellbore (b), and Ring showing cleat distribution and image interpreted cleat points (c).

Training image generation:
We coded a program in MATLAB to generate cleats distribution based on the cleat spacing shown in Figure 4. Then the generated cleats were imported into Petrel as FAB data because Petrel cannot generate butt cleats terminated by face cleats (Petrel, 2014). We then built a 1000×1000 2D grid with grid size of 1 mm in x- and y- direction to store cleats as shown in Figure 6a for one realisation because MPS is a pixel-based sequential simulation algorithm.

Cleats modelling by using MPS:
A 3D grid with grid cells of 1000×1000×4 in x-, y- and z-direction was built firstly. The grid size is 1 mm in x- and y- direction and equals coal seam thickness in vertical. The training image (Figure 6a) was used to create pattern by using an ellipsoid search mask (Petrel, 2014) with radius of 50×50×1 in x-, y- and z-direction. We then converted the log interpreted cleats (Figure 3) to a probability model. Finally, MPS was used to generate cleats distribution with distribution pattern from Figure 6a, conditioning data from Figure 3 and face cleat azimuth from Figure 5. Figure 6b shows the modelled cleats and matrix within 50 cm of wellbore for one realisation.

DISCUSSION AND FUTURE WORKS

This study presents a workflow to build cleats distribution near a wellbore by integrating the image log interpreted cleats, cleats spacing data from coal core observation and MPS method. The built cleats and matrix model can help to analyse near-wellbore coal properties, coal seam gas production, and well testing performances. More training images from µCT scanned cleats (Figure 7) will be used in the future. Well testing (Figure 8) or production data will be used to optimise the cleats distribution model.

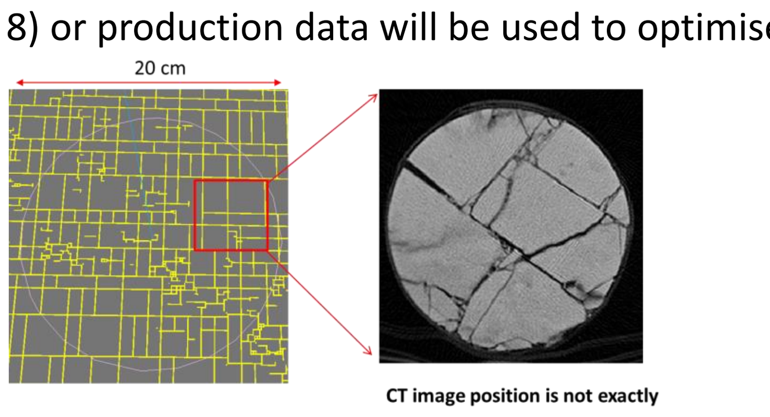

Fig. 7. Cleats distribution compared with CT extracted cleats. Note that the position of this CT image is not exact.

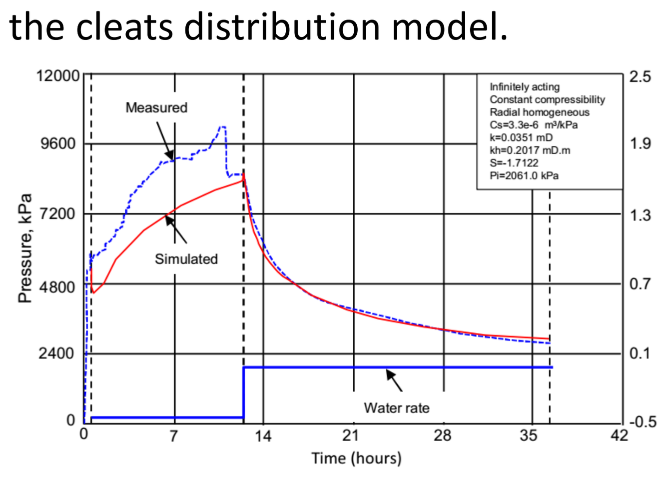

Fig. 8. Using well testing data to optimise cleats model (from Zhou and Yao, 2014)

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