International Journal of Coal Geology 191 (2018) 66–79

Contents lists available at ScienceDirect

International Journal of Coal Geology

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

Petrographical and geochemical characterization of sub-bituminous coals from mines in the Cesar-Ranchería Basin, Colombia

Qiulei Guo, Ralf Littke, Laura Zieger*

Energy and Mineral Resources Group (EMR), RWTH Aachen University, Lochnerstr. 4-20, 52056 Aachen, Germany

ARTICLE INFO

Keywords:
Coal petrography
Columbia
Cesar-Ranchería Basin
Organic geochemistry
Depositional environment
Ash-sulfur plot
Rock-Eval pyrolysis
Coal

ABSTRACT

Tertiary coals from the La Jagua and Calenturitas coal mines in the Cesar sub-basin, Colombia were investigated for the first time using organic-petrological and organic-geochemical methods to assess the thermal maturity and palaeoenvironmental conditions during peat accumulation. Thirteen seams were sampled from the Los Cuervos formation at two mines. Evaluation based on organic petrological analyses and Rock-Eval pyrolysis reveals that the coals are thermally immature and of sub-bituminous B to sub-bituminous A rank with a predominance of type III, mixed with type II kerogen. 22S/(22S + 22R) homohopane, $T_s/(T_s + T_m)$, MPI, MPR and 1-MP/9-MP ratios are very low. This low thermal maturity corresponds to high volatile matter contents.

Petrographically, the La Jagua and Calenturitas coals are dominated by vitrinite, with low to high amounts of inertinite and low to moderate amounts of liptinite. The detailed petrographic data indicate a predominantly herbaceous plant input and oxidative conditions during deposition, mostly with strong tissue destruction. Further conclusions are deduced from petrographic ratios such as tissue preservation-, gelification-, groundwater_{AC}- and vegetation indices, ash- and sulfur contents, iso- and *n*-alkane distribution, and 17α(H)-homohopane ratio. In summary, the data support a formation in tropical, ombrogenic, rather wet peats with high bacterial activity.

1. Introduction

The Cesar-Ranchería Basin (CRB; Fig. 1) contains coal deposits of the Mid-Late Paleocene Los Cuervos and Cerrejón Formations and is also considered to hold the largest coalbed methane (CBM) potential in Colombia. Total gas reserves for CBM are estimated to range between $3.6 \times 10^{11}$and 7.1×10^{11} m^3 (Garcia-Gonzalez, 2010). Although some scientific studies have dealt with the tectonic history of the CRB (Montes et al., 2005; Cardona et al., 2011a, 2011b; Kroehler et al., 2011; Bernal-Olaya et al., 2015), the stratigraphy (Mora and Garcia, 2006; Ayala et al., 2012), basin evolution and paleogeography (Villamil, 1999; Escalona and Mann, 2011), only little work was published on the organic geochemical and petrographical composition of the Paleogene coals (Arango and Blandón, 2006). Both organic petrographic and organic geochemical data of coals can be used to better understand the evolution of the original mire ecosystems (Horsfield et al., 1988; Amijaya et al., 2006; Bechtel et al., 2007; Böcker et al., 2013). With respect to organic petrography, different interpretation schemes have been developed based on ratios of different macerals, partly also taking into consideration the presence of minerals or ash (Diessel, 1986, 1992; Mukhopadhyay, 1986, 1989; Calder et al., 1991; Kalkreuth et al., 1991; Littke, 1987; Jasper et al., 2010; Stock et al., 2016). Care has to be taken, because some of these ratios are only useful for low or high rank coals, respectively or have been calibrated for specific peats, e.g. from tropical environments. Nevertheless, the here studied Columbian subbituminous coals seem to have an ideal maturity for adoption of organic petrological methods and parameters. Similarly, organic geochemical methods based on hydrocarbon biomarkers are least suitable for very low-mature or very high-mature samples, but should be well-suitable for these Columbian coals. In this context, the goal of this study was to reconstruct the environmental conditions leading to the present-day low-rank coals of the CRM by applying a combined organic petrographic and organic geochemical approach.

1.1. Geological setting

The Cesar-Ranchería Basin is located southeast of the thrust front of the Caribbean-South American subduction plate margin and near the north-western apex of the triangular Maracaibo Block in the east. The CRB is an intermontane basin bounded by the Oca wrench fault in the north and the Bucaramanga-Santa Marta (BSM) Fault in the southwest (Fig. 1). The Cerrejón and Perijá thrust faults form the eastern and the

* Corresponding author.
E-mail address: laura.zieger@emr.rwth-aachen.de (L. Zieger).

https://doi.org/10.1016/j.coal.2018.03.008
Received 16 February 2018; Received in revised form 22 March 2018; Accepted 22 March 2018
Available online 26 March 2018
0166-5162/

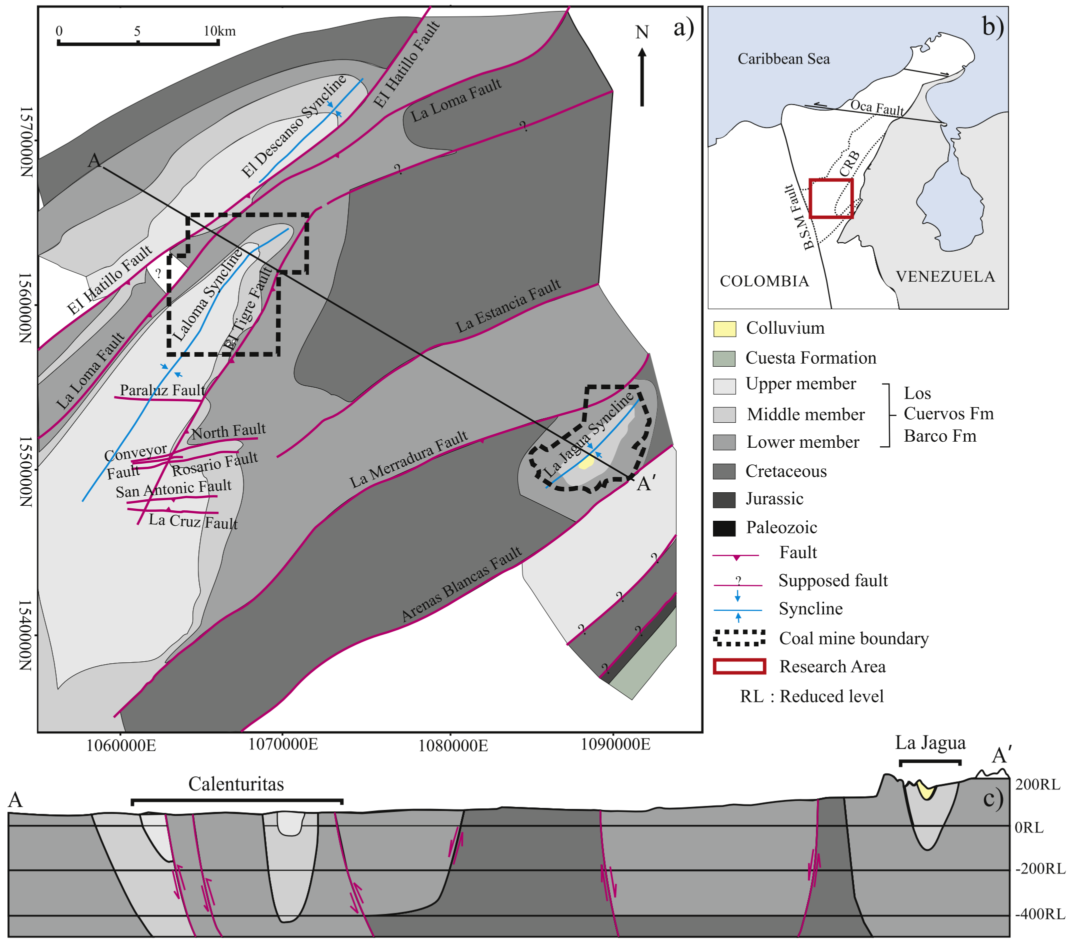

Fig. 1. Geological map (a), location (b), and cross section (c) of the Cesar-Ranchería Basin.
Modified after ADV-SY-03728, 2011.

Sierra Nevada de Santa Marta massif the northwestern boundaries. The CRB is subdivided in its centre into the southern Cesar sub-basin (CB) and the northern Ranchería sub-basin (RS) by the Valledupar basement high (Mora and Garcia, 2006; Cardona et al., 2011b; Baquero et al., 2014). The faults in the CB show a complex pattern with a NE-SW main trend and a secondary E-W trend. The basement of the CRB consists of Precambrian to Palaeozoic igneous and metamorphic rocks (Mann et al., 2006; Sanchez and Mann, 2015). The stratigraphic record of the approximately 2 km thick clastic basin-fill ranges from Palaeozoic to Holocene age (Fig. 2). The Triassic and Jurassic sediments consist of sandy to conglomeratic redbeds and volcanic rocks and are unconformably overlain by Cretaceous marine sediments, including organic-rich shales and abundant limestones with occasional thin interbedding of sandstone layers (Mann et al., 2006; Mora and Garcia, 2006; Sanchez and Mann, 2015). The sedimentation of the Cenozoic strata within the CRB is associated with the collision of the Caribbean and the South-American plates and the subsequent accretion of a Paleocene Arc (Cardona et al., 2011a, 2011b; Mann et al., 2006). The Paleogene Formations are grouped into two sequences. The lower sequence is represented by the terrestrial Barco and Cuervos Formations in the CB, which consists of claystone, siltstone, and several coal seams and the shallow marine Hato Nuevo and Manantial Formations, which turns into the terrestrial coal-bearing, mudstone-rich Cerrejón Formation in the RB (Mora and Garcia, 2006; Bayona et al., 2007). The depositional setting of the sediments within the Cerrejón Formation evolved from an estuarine-influenced coastal plain to a fluvial-influenced coastal plain (Jaramillo et al., 2007). The fossil record of these sediments shows a diverse flora, consisting mainly of palmae and araceae (Wing et al., 2009), suggesting a coastal plain environment with tropical rainforest vegetation, which was incised by large river systems (Head et al., 2009; Hastings et al., 2011; Cadena et al., 2012). Palynological data indicate that the coal-swamp floras were dominated by palmae and other angiosperm species (Jaramillo et al., 2007), but this has to be regarded with caution, because spores and pollen can derive from other places and are not necessarily representative of the vegetation, the coal derived from.

1.2. Sampling and methods

Thirty-six samples from thirteen coal seams were collected from the La Jagua (LJM) and the Calenturitas (CM) coal mines, situated in the southern CRB (Fig. 1). Twenty samples were collected from seven coal seams within the Cuervos Formation with thickness ranging from 1.25 to 4.5 m within the CM and sixteen samples were taken from six different coal seams within the LJM with thicknesses between 1.8 m and 5.2 m (Fig. 3). All samples were collected roughly every meter. Measurements were conducted on selected pieces and powdered (< 200 μm) samples, respectively for organic petrographical and proximate analyses and on extracted liquids for organic geochemical analyses.

1.2.1. Proximate and bulk geochemical analyses

The proximate analyses include the determination of ash content, volatile matter, and moisture contents. The measurements followed standard procedures described in DIN51719 (1997), DIN51720 (2001), and DIN51721 (2001), respectively. Total organic carbon (TOC) and