International Journal of Coal Geology 139 (2015) 217–227

Contents lists available at ScienceDirect

International Journal of Coal Geology

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

Reprint of "Solid bitumen occurrences in the Arruda sub-basin (Lusitanian Basin, Portugal): Petrographic features"☆

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ARTICLE INFO

Article history:
Received 31 January 2014
Received in revised form 3 June 2014
Accepted 27 June 2014
Available online 1 November 2014

Keywords:
Impsonite
Pyrobitumen
Bitumen reflectance
Vitrinite reflectance
Thermal maturity

ABSTRACT

The Middle Jurassic to Cretaceous sedimentary record in the Lusitanian Basin (Portugal) reveals the presence of disseminated solid bitumen. The present work is focused on the petrographic characteristics of solid bitumen identified in the Freixial-1 and Benfeito-1 boreholes (Arruda sub-basin, Lusitanian Basin) that display different thermal maturities. Microscopy techniques (reflected and transmitted white light, incident blue light and SEM) and organic geochemistry analyses (total organic carbon, total sulfur and insoluble residue) were used to study these samples. From the results obtained by optical microscopy (fluorescence and reflectance) it was possible to distinguish three types of solid bitumen. They were labeled as solid bitumen A, present in all the samples, solid bitumen B and solid bitumen C, these ones observed in some of them. They correspond to allochthonous (migrated) bitumens. In blue incident light, some bitumen do not show fluorescence while others reveal fluorescence that range from yellow (solid bitumen B) to dark brown (solid bitumen A). All bitumens are optically isotropic. Bitumen reflectance varies between 0.70 and 2.60% R_r, and the vitrinite reflectance ranges from 1.11 to 1.48% R_r. Based on the % R_r values, the solid bitumen identified in these samples are classified as impsonite (epi- and cata-) or pyrobitumen. No relation can be established with confidence for the reflectance of bitumens with the reflectance of vitrinite.

1. Introduction

Solid bitumen occurs in several basins all over the world associated to source rocks as well as reservoirs rocks. Solid bitumens ("migrabitumen") are secondary organic matter products that are filling voids and fractures in rocks (Jacob, 1989) resulting from advanced stages of thermal maturation (Curiale, 1986) and can occur in carbonate and siliciclastic rocks. Its occurrence in petroliferous basins becomes a topic of interest for organic petrologists and organic geochemists. Their presence can be an oil and/or gas indicator as well as an indicator of maturity, especially in sedimentary sequences that are destitute of vitrinite, and can also provide some information on the migration path (e.g., Gentzis and Goodarzi, 1990; Jacob, 1989; Landis and Castaño, 1995). Furthermore, the presence of certain types of solid bitumen (e.g., pyrobitumen) can deteriorate the reservoir quality since it acts as cement reducing the porosity and permeability of the reservoir (e.g., Huc et al., 2000; Walters et al., 2006).

Generally, solid bitumens are accumulations of organic matter that contain an important solid phase and are found in petroliferous systems (e.g., Landis and Castaño, 1995) but its definition depends on whether it is being studied by organic petrologists or by organic geochemists. For organic petrologists, solid bitumens correspond to solid organic matter that is filling voids and fractures in sedimentary rocks. The parameters used for its classification are based on the physical properties such as reflectance, fluorescence intensity, micro-solubility and micro-flowpoint (Jacob, 1989). Attending to these parameters, Jacob (1989) classified the solid bitumen as ozocerite, wurtzilite, albertite, asphalt, gilsonite, glance pitch, grahamite and impsonite (epi-, meso- and cata-impsonite). On the other hand, the organic geochemists define solid bitumen as the organic matter soluble in organic solvents (Tissot and Welte, 1984). Curiale (1986), using biomarker data from organic rich source rocks, defined two types of bitumen: a pre-oil bitumen with low maturity and that migrates small distances, and a post-oil bitumen, usually called pyrobitumen, that represents the residue of the oil. Despite the different definitions, the use of petrographic and geochemical techniques allows a better understanding of this type of organic material. Many studies enable a better understanding on the origin of solid bitumen and using their characteristics to evaluate the thermal maturity of the sequences: some studies are focused on geochemical analyses

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DOI of original article: http://dx.doi.org/10.1016/j.coal.2014.06.023.

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http://dx.doi.org/10.1016/j.coal.2014.10.012
0166-5162/

(Curiale, 1986; Curiale et al., 1983; George et al., 2007; Huc et al., 2000; Hwang et al., 1998; Kelemen et al., 2008, 2010); and others also include petrographic analysis (e.g., Bertrand, 1990, 1993; Bertrand and Héroux, 1987; Fowler et al., 1993; Gentzis and Goodarzi, 1990; Jacob, 1989; Landis and Castaño, 1995; Riediger, 1993; Schoenherr et al., 2007; Shalaby et al., 2012; Stasiuk, 1997).

The Lusitanian Basin (LB) is an Atlantic margin rift basin located on the western board of the Iberian Peninsula that was filled with sediments from the Upper Triassic to the Cretaceous covered with Cenozoic sediments (e.g., Azerêdo et al., 2003; Wilson, 1988).

Benfeito-1 and Freixial-1 boreholes (Arruda sub-basin, Central Sector of LB; Fig. 1) revealed the presence of dispersed solid bitumen in two carbonate formations (Candeeiros and Cabaços Formations). Candeeiros Formation (Bathonian) consists predominantly of carbonate facies deposited in a carbonate ramp with shallow waters (Carvalho et al., 2005). The Cabaços Formation, the lowermost formation of the Upper Jurassic from the LB, comprises limestone, marls and anhydrites beds (e.g. Azerêdo et al., 2002; Leinfelder and Wilson, 1989; Wilson, 1979) and corresponds to a lacustrine marginal marine environment (e.g., Azerêdo et al., 2002; Carvalho et al., 2005; Leinfelder and Wilson, 1989).

So far, there is no published data on the characteristics and origin of solid bitumen in the Lusitanian Basin but its occurrence has been reported in the Bombarral sub-basin (Central Sector of LB; Gonçalves et al., 2013) and in Lower Tagus sub-basin (Southern Sector of LB; Gonçalves et al., 2014). This paper is a first approach to the study of solid bitumen existing in the Lusitanian Basin. The main purpose of this work is to study the optical characteristics of the different solid bitumen identified in the carbonate rocks of the Candeeiros and Cabaços Formations using incident and transmitted light microscopy, and scanning electron microscopy (SEM).

2. Samples and methods

Eighteen samples were chosen for this research, twelve from Cabaços Formation and six from Candeeiros Formation (Table 1). The samples belong to Benfeito-1(Bf-1) and Freixial-1 (Fx-1) boreholes drilled in the Arruda sub-basin (Lusitanian Basin, Portugal, Fig. 1). The selected samples do not show evidence of weathering. According to Littke et al. (1991) the microscopic appearance of pyrite seems to be the most reliable indicator of source rock weathering because pyrite is a ubiquitous constituent in most organic matter-rich sediments. In sediments affected by weathering many pyrite crystals seem to be completely replaced by iron oxide or iron hydroxide. Thus, the organic matter in the studied samples contains exclusively fresh pyrite revealing according to these authors that they are not affected by weathering.

Determination of total organic carbon content (TOC), total sulfur content (TS) and insoluble residue (IR) was carried out in the studied samples. They were analyzed using a LECO analyzer SC144 after eliminating the carbonate fraction by acidification (50% HCl).

The preparation of the slides for palynofacies analysis was performed according to the palynofacies procedures through the isolation of non-oxidative organic matter proposed by Mendonça Filho et al. (2011) and Tyson (1995). The analysis involved identification and counting of the particles from the phytoclast, amorphous organic matter (AOM) and palynomoph groups (Mendonça Filho et al., 2011, 2012; Tyson, 1995) and solid bitumen using microscopic techniques (both transmitted white and incident blue lights).

Three samples (Fx25, Fx26 and Fx27) were selected for SEM observation. The concentrated organic matter obtained for palynofacies analysis was placed on a carbon ribbon on a plug of aluminum. After 24

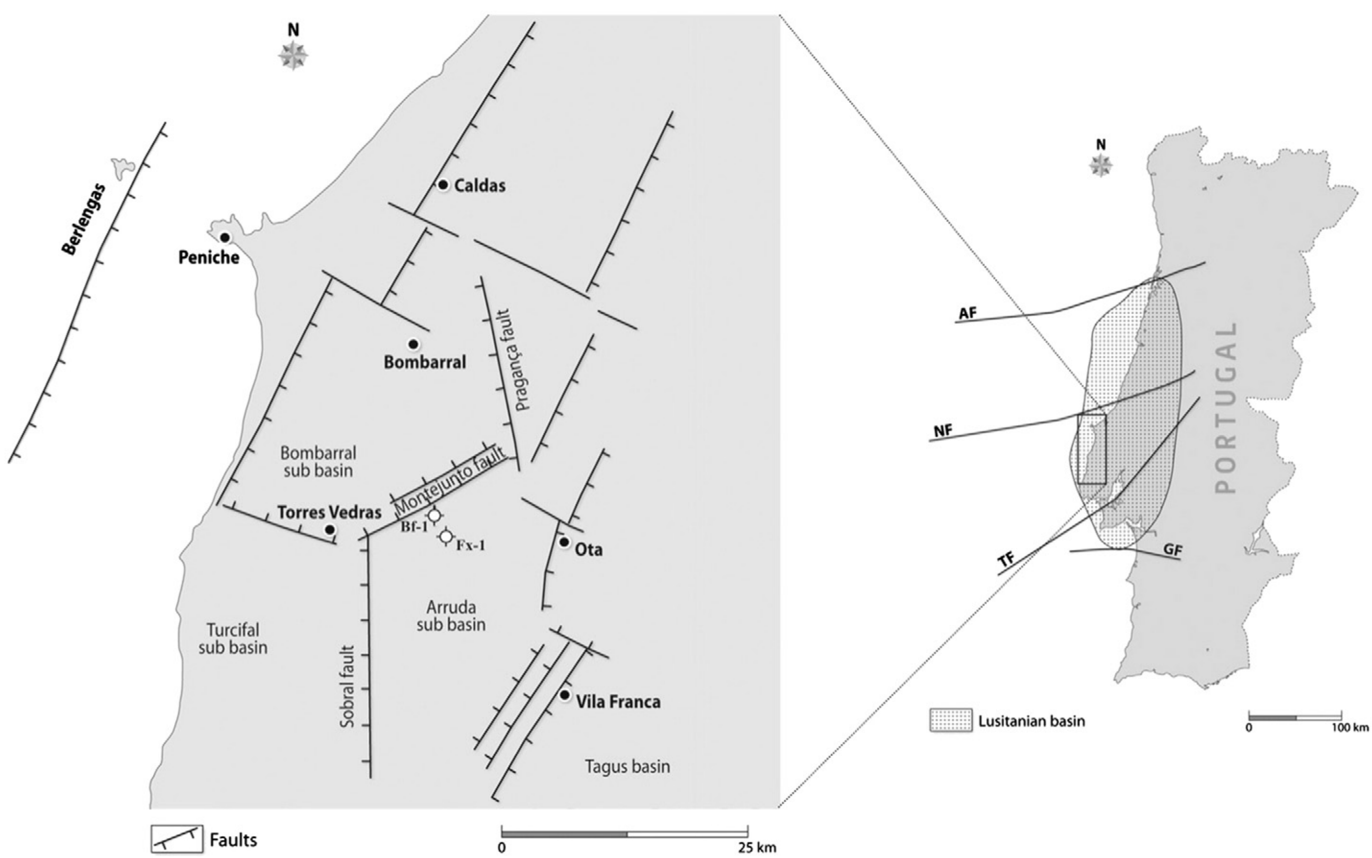

Fig. 1. Geographic and tectonic settings of the Lusitanian Basin (modified from Alves et al., 2002; Montenat et al., 1988) and location of the Benfeito-1 and Freixial-1 boreholes. AF: Aveiro Fault; NF: Nazaré Fault; TF: Tagus Fault; GF: Grândola Fault; Bf-1: Benfeito-1 borehole; Fx-1: Freixial-1 borehole.