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Paleoenvironmental reconstruction by means of palynofacies and lithofacies analyses: An example from the Upper Triassic subsurface succession of the Hyblean Plateau Petroleum System (SE Sicily, Italy)

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ABSTRACT

A combined palynofacies and lithofacies analysis was carried out on two borehole successions (Streppenosa 1 and Bimmisca 1) from the Hyblean Plateau Petroleum System (SE Sicily, Italy). It was found that both the wells penetrated the most important source and seal rocks of the Sicilian region (Noto and Streppenosa formations), previously assigned to the Late Triassic-Early Jurassic, deposited within a carbonate platform-basin system. Based on new palynological data, the organic rich succession (Noto Formation and Upper Streppenosa Member) can now be entirely assigned to the Rhaetian, thus constraining its deposition to a time interval characterized by increasing global humidity and seasonality. The integrated palynofacies and lithofacies data enabled characterization of the timing of the drowning phases of the carbonate platform-basin system as being controlled by relative sea level changes mostly triggered by the Triassic extensional tectonic activity. During the first phase of the relative sea-level rise, clayey and organic-rich sediments were deposited only in the deepest portion of the basin. As the sea level continued to rise, the entire system drowned completely and suboxic-anoxic basinal sediments were deposited across the whole Hyblean region, onlapping the shallow-water facies. In the meantime increasing global humidity contributed to an increased freshwater input in the marine depositional system as documented by the presence of fern spores and clay. It caused water stratification and subsequent anoxia at marine basins, favoring the preservation of sedimentary organic matter. This atmospheric change could be related to the degassing of the Central Atlantic Magmatic Province.

1. Introduction

The temporal and spatial distribution of Phanerozoic organic rich sediments is related to a combination of variables: organic productivity, appropriate sedimentation rates and organic matter preservation (Tyson, 2001, 2005; Katz, 2005; Trabucho-Alexandre et al., 2012). Organic carbon rich sediments have been commonly attributed to widespread ocean anoxia and to the associated water stratification (Tyson and Pearson, 1991; Wignall and Newton, 2001; Pancost et al., 2004; Harris, 2005; Meyer and Kump, 2008). Other theories suggest that a combination of high primary productivity and a low sedimentation rate promotes the accumulation of large amounts of organic matter due to a relatively low degree of dilution by siliciclastics and skeletal debris (Lallier-Vergès et al., 1995; Perkins et al., 2008). During the Late Triassic – Early Jurassic times in the western Tethys realm, the deposition of organic rich clay and marly successions seems to have coincided with climate warming and increasing rainfall and runoff (Korte et al., 2009; Bonis et al., 2010; Haas et al., 2010, 2012; Michalik et al., 2010; Berra, 2012). This has been interpreted as a consequence of intense monsoonal activity (Parrish, 1993; Satterley, 1996; Sellwood and Valdes, 2007; Bonis and Kürschner, 2012). In addition, the onset of igneous and volcanic activity within the Central Atlantic Magmatic Province (CAMP), is generally believed to have strongly influenced the climate change due to the release of volcanic gases (mainly CO_2 and SO_2) into the ocean–atmosphere system (Marzoli et al., 2004; Cirilli et al., 2009; van de Schootbrugge et al., 2009; Lucas et al., 2011; Ruhl et al., 2011; Schaller et al., 2011; Pálfy and Zajzon, 2012; Vajda et al., 2013; Bond and Wignall, 2014; Lindström, 2016; Davies et al., 2017; Lindström et al., 2017b). Consequently, the end-Triassic mass extinction (ETE) has been attributed to the huge amount of greenhouse-gas emissions in the atmosphere and in the ocean water, and associated with the ≈3–6% negative carbon isotope excursion, recorded in both terrestrial and marine environments (Schoene et al., 2010; Whiteside et al., 2010; Ruhl et al., 2011; Dal Corso et al., 2014; Lindström, 2016;

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Lindström et al., 2017b). Recent high-precision U-Pb ages from CAMP mafic intrusive units (Davies et al., 2017) and large scale correlations based on a set of integrated biotic, geochemical and radiometric data (Lindström et al., 2017b), highlight that magmatic activity started about 100 Kyr before the earliest known eruptions, providing evidence of the causal relation between CAMP and ETE. The resulting increase in the fresh water supply and nutrient input in the marine environments, via river runoff, led to water density stratification and increased primary productivity which led to the accumulation and preservation of organic matter in anoxic marine basins.

The overall aim of this study is to provide new insights into the factors triggering the accumulation and preservation of organic matter within a given paleoclimatic and paleogeographic scenario related to the well-known source and seal rocks of the Hyblean Petroleum System, in south eastern Sicily (Italy). We combined palynofacies and lithofacies analyses of two on-shore wells from Sicily in order to interpret the paleoenvironmental and paleoclimatic conditions and the input of organic matter preserved in the sediments. The data provided in this paper complement and integrate those presented by Cirilli et al. (2015) regarding another on-shore well (Pachino 4) drilled in the same area.

2. Geological setting

In the last few decades, Eni Upstream and Technical Services have carried out many geological studies, in southeastern Sicily on-shore and off-shore, following exploration activity (Fig. 1) (Frixa et al., 2000; Trincianti et al., 2015 for references). The studied wells are located in the south east of Sicily (Hyblean Plateau) which is characterized by an over 5 km thick Triassic-Neogene sequence, lying above a 20–25 km thick sequence with African affinity and acting as a foreland basin during Neogene Alpine orogenesis (Patacca et al., 1979; Yellin-Dror et al., 1997; Catalano et al., 2000, 2002, 2013; Granath and Casero, 2004; Finetti et al., 2005). Small and large-scale paleogeographic reconstructions reveal that Sicily has been located along the African - European plate boundary from Paleozoic times (Ruiz-Martínez et al., 2012; Catalano et al., 2013; Berra and Angiolini, 2014; Scotese and Schettino, 2017). Starting from Triassic, the west-central Mediterranean platform (Apulia-Adria) was broken apart by the same tectonic processes that caused the opening of the Central Atlantic. After separation of north west Africa (northern Gondwana) from Eastern North America, Adria, Apulia (including Sicily) and southern Turkey continued to be part of the African Plate (Catalano et al., 2002, 2013; Robertson et al., 2003; Finetti et al., 2005; Berra and Angiolini, 2014; Scotese and Schettino, 2017). The extensional faulting was accompanied by regional and large-scale fissural basaltic volcanism at least since the Triassic. Intercalations of mafic volcanics have been recorded in several wells of the Hyblean Plateau at different stratigraphic levels (Patacca et al., 1979; Rocchi et al., 1996; Granath and Casero, 2004; Finetti et al., 2005; Scotese and Schettino, 2017). Beginning in the Late Triassic, the whole Hyblean Plateau region was occupied by a wide shallow water carbonate platform (represented by the Sciacca Formation). The extensional phase related to the continental rifting caused the carbonate platform to break-up and this triggered the onset of a platform to basin system (Patacca et al., 1979; Brosse et al., 1988; Frixa et al., 2000). Shallow-water carbonate deposits (Noto Formation) covered the northern part of the area, while a deep anoxic-suboxic intraplatform basin developed southward (Fig. 1). The Noto Formation (about 300 m thick) includes at least three interfingering facies. The first facies is spread throughout the Hyblean Plateau and consists of limestones (mudstones and wackestones), often dolomitized and recrystallized, interlayered with organic rich black shales. The second facies, is only found at the

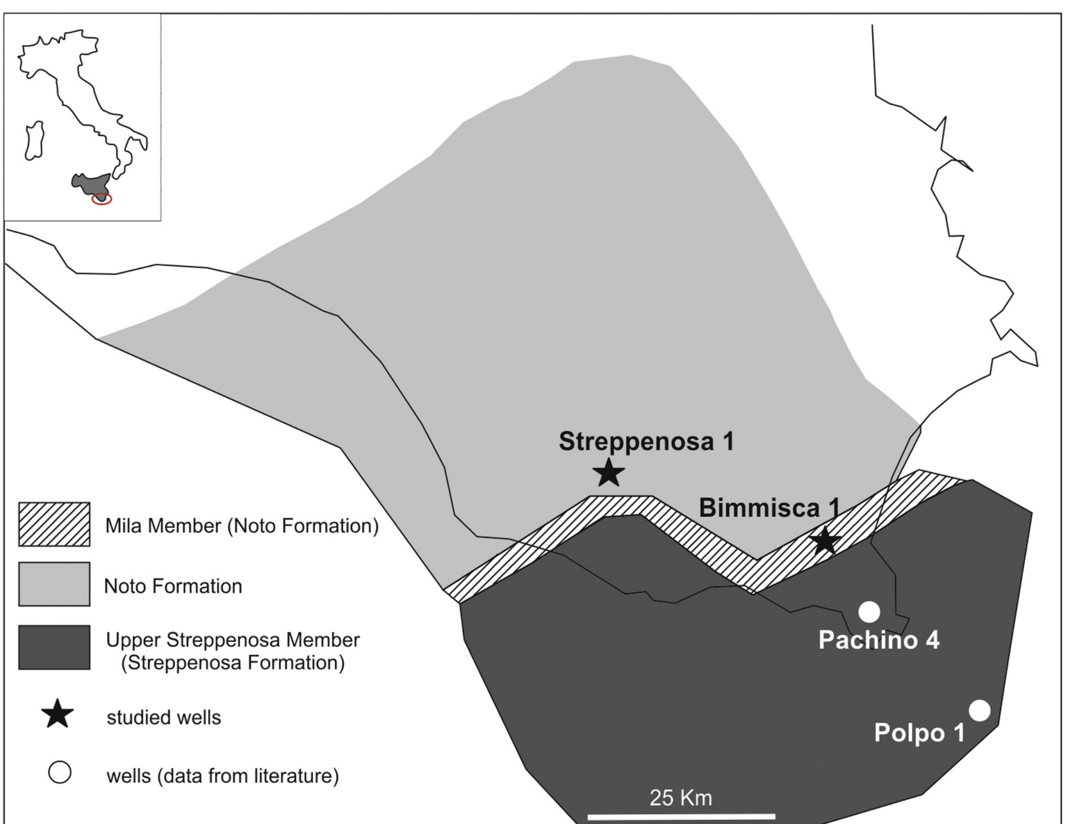

Fig. 1. Location of the study wells in the Late Triassic paleogeographic scenario of the Hyblean Plateau (SE Sicily), at the initial drowning phase (modified from Cirilli et al., 2015); stars indicate the location of the studied wells: Streppenosa 1 and Bimmisca 1, which are the focus of this paper. Circles indicate the location of the Pachino 4 well (Cirilli et al., 2015) and the Polpo 1 (Frixa et al., 2000).