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Correlation of Palynomorph Darkness Index and vitrinite reflectance in a submature Carboniferous well section in northern Saudi Arabia

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Abstract

Palynomorph Darkness Index (PDI) determinations are presented from a sub-mature, cored, Carboniferous well section in northern Saudi Arabia and are correlated to Vitrinite Reflectance (Ro) and Vitrinite Reflectance (Calculated) results from the same section. PDI values from smooth, simple miospores range from 34–57%, whereas mean Ro and Vitrinite Reflectance (Calculated) both range from *ca.* 0.4–0.6%. The PDIs of the Recent spores *Lycopodium clavatum* and *Cheilanthes viridis* were also determined for comparative purposes. Considerable variation in PDI was recorded in all the samples investigated. A very tentative correlation of PDI to Ro is presented for samples with a range of thermal maturity from those unaffected by any heating, to those at the top of the oil window.

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1. Introduction

Following publication of Staplin's (1969) Thermal Alteration Index (TAI), numerous qualitative schemes relating palynomorph colour to thermal maturity have been established. Many of these are based on reference sets of palynomorph specimens or photomicrographs, and most employ numerical scales for colour categories. However, the numbers used in these schemes are simply labels with no quantitative significance. The few quantitative methods that have been proposed typically use expensive equipment not generally available to most workers, for example, the system based on microspectrophotometry described by Marshall (1991). The various methods for assessing maturity using palynomorph colour are comprehensively reviewed by Goodhue and Clayton (2010) and Hartkopf-Fröder et al. (2015).

Palynomorph Darkness Index (PDI) was described by Goodhue and Clayton (2010) as a rapid and inexpensive method

of quantitatively describing palynomorph colour. This scheme differs from most earlier attempts in that it integrates colour intensities to produce greyscale values, rather than considering three variables (red, green and blue intensities). Although its methodology has been clearly described, the usefulness of PDI has been limited by the absence of correlation to vitrinite reflectance (VR), the industry standard for determination of maturity.

Well 667-44 is a cored stratigraphic borehole drilled in 2009 by Saudi Aramco in northern Saudi Arabia. It includes one of the most complete Permo-Carboniferous successions in the region and is intended to serve as a litho- and biostratigraphic reference section for the Mississippian Berwath Formation. The location of the well and its generalised lithostratigraphy are shown in Figs. 1 and 2 respectively. In terms of thermal maturity, the section investigated ranges from submature at its top, to the ceiling of the oil window at its base, constituting a critical interval for the correlation of PDI to VR. In order to determine the PDI of palynomorphs that had not been subjected to any form of maturation process, spores of a Recent fern and lycopod were also studied.

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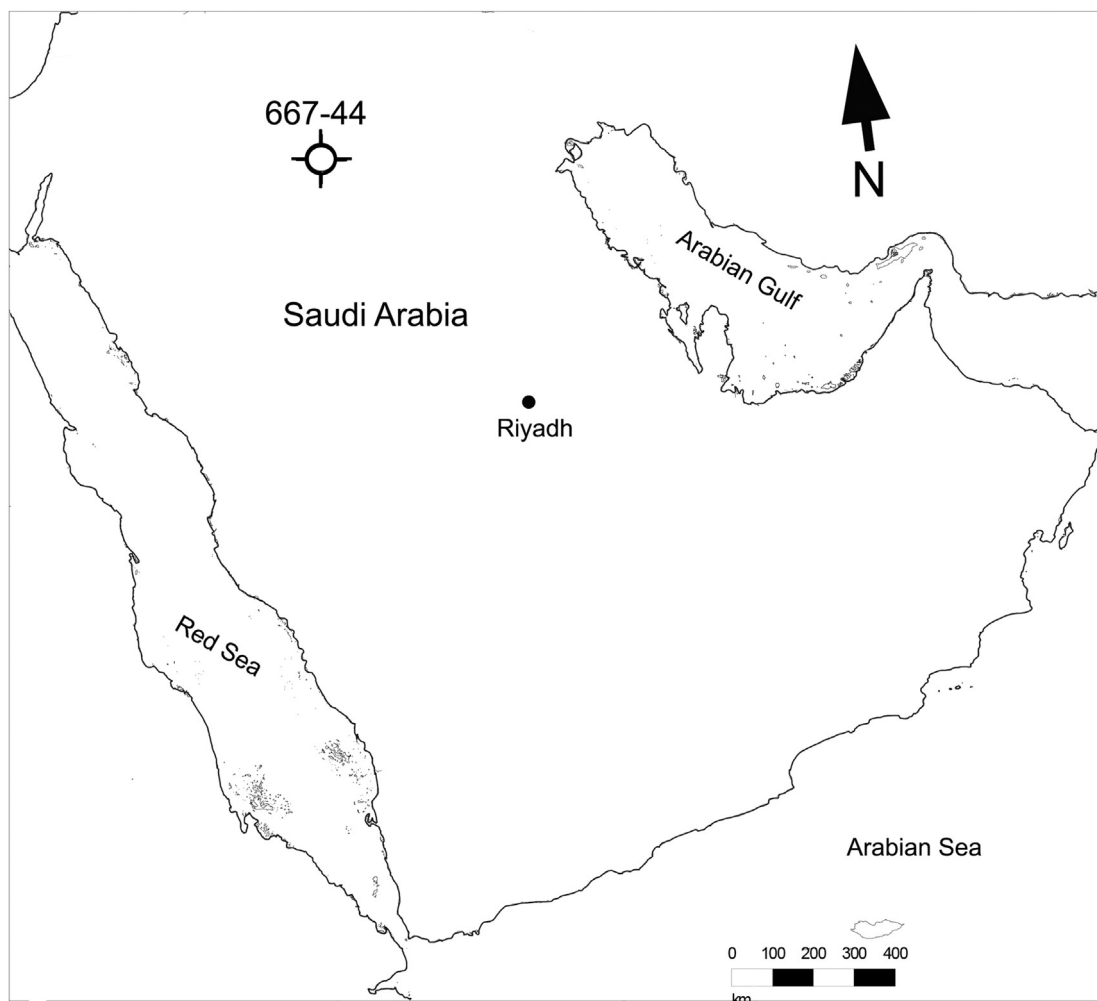


Fig. 1. Location of Well 667-44.

2. Materials and methods

2.1. Sampling and sample processing

Grey mudrock samples were collected from the core for PDI, VR (R_0) and $VR_{\text{calculated}}$ determination. For PDI, standard palynological extraction and mounting techniques were employed, using hydrofluoric acid but no oxidation.

For VR, whole-rock plugs were prepared using cold-setting epoxy resin. These were polished and detrital organic-matter fragments were identified microscopically in reflected and fluorescent light. Depending on fragment size, one or more random reflectance measurements (R_0) was made on each fragment using the standard technique coal petrography and reflectance investigation technique of Bustin et al. (1985).

Two miospore genera were used for PDI determination in Well 667-44; *Punctatisporites* spp. and *Waltzispota* spp. Both produced consistent results but the latter only occurred commonly in two samples. The Recent spores investigated were obtained from two sources. Spores of the lycopod, *Lycopodium clavatum* were extracted from commercially available *Lycopodium* tablets which were dissolved in warm water. The spores were then concentrated by sieving at 15 μm , and

mounted using Cellosize[®] dispersal agent and Elvacite[®] cold mounting medium. Spores of the fern, *Cheilanthes viridis* were obtained by shaking pinnules with mature sporangia over cold water, then concentrating and mounting the spores using the method described above. No chemical treatment was employed. Examples of the fossil and Recent palynomorphs used in this investigation are illustrated in Plate 1.

2.2. PDI determination

RGB intensities were measured by the method described by Goodhue and Clayton (2010), using a Nikon Eclipse E600 microscope with a 12 V, 100 W halogen bulb, NCB filter, $\times 40$ and $\times 60$ plan fluor objective lenses, and a DXM1200 digital camera with ACT-1 software. The microscope was set up for Kohler illumination. Default settings were used for the camera with the NCB filter installed. With a slide in focus, the lamp voltage and condenser diaphragm were carefully adjusted to obtain RGB intensities less than, but as close as possible to 255, 255, 255. The automatic white balance control was not used. Images were captured, representative areas for measurement selected, and values for RGB intensity obtained.

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