

INTRODUCTION

A common problem encountered in assessing hydrocarbon source rock maturity is insufficient woody material for determination of vitrinite reflectance (VR) – a particular problem with all pre-Devonian rocks (figure 1b) and many black shales (figure 1c). Palynomorph Darkness Index (PDI) is a new thermal maturity indicator calculated from measurement of the red, green and blue (RGB) intensities of light transmitted through palynomorphs, using standard palynological microscopes and digital cameras.

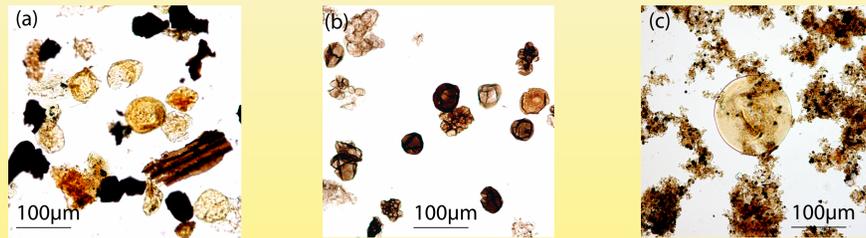


Figure 1 a. Late Devonian Bedford Shale (Kentucky, USA) containing both palynomorphs and vitrinite; b. Precambrian shale (Kola Peninsula) with palynomorphs, but no vitrinite; c. Early Mississippian Sunbury Shale (Kentucky, USA) - a typical black shale containing palynomorphs, but very little vitrinite.

METHOD

This method represents a new and simplified approach to determining palynomorph colour, based on the integration of red, green and blue intensities to produce a single greyscale value. This is then converted to the Palynomorph Darkness Index (PDI) using NTSC (National Television System Committee) and JPEG (Joint Photographic Experts Group) RGB to greyscale conversion:

$$Y = 0.299R + 0.587G + 0.114B$$

where Y is the calculated greyscale value and R, G & B are the red, green and blue intensities

PDI ranges from 0% (white) to 100% (black) and is calculated as:

$$PDI (\%) = 100 - (100Y_a / 255)$$

Palynomorph colours are often determined in transmitted light which is not 'pure' white, i.e. where one or more measured white background intensities (R_b, G_b, B_b) is less than 255. In these cases, the following correction can be made:

$$Y_a = (0.299R * 255 / R_b) + (0.587G * 255 / G_b) + (0.114B * 255 / B_b)$$

where Y_a = adjusted greyscale value

CALIBRATION

Two different types of material were used to determine the platform-dependence of PDI. The first comprised standard photographic filters of various colours. The second, specimens of the unoxidised Palaeozoic prasinophyte, *Tasmanites* sp. and the trilete miospore, *Ambitisporites* sp. (figure 2).

A selection of large (400–600 µm) specimens of *Tasmanites* from a tasmanite oil shale in the Lower Permian Quamby Formation from Latrobe, northern Tasmania was used in addition to twelve small (40–90 µm) specimens of *Tasmanites* from the Silurian Mudawwara Formation of Jordan. Twelve specimens of the trilete miospore, *Ambitisporites*, from the Silurian KishSha Formation were also investigated.

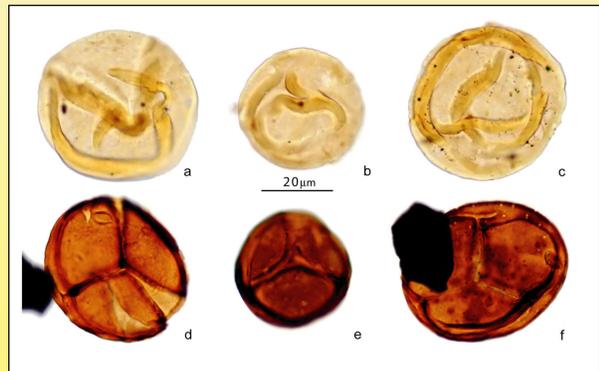


Figure 2. (a-c) *Tasmanites* sp. Mudawwara Formation (Silurian) Jordan. (d-f) *Ambitisporites* sp. KishSha Formation (Silurian) Jordan.

RGB intensities of light transmitted through filters (figure 3) and palynomorphs (figure 4) were measured independently by authors using two different microscope / camera combinations designated, 'Leitz' and 'Nikon 1', and PDIs were then calculated. There is excellent linear correlation between the Leitz and Nikon 1 microscopes, suggesting that closely comparable results can be obtained from different types of equipment with suitable calibration.

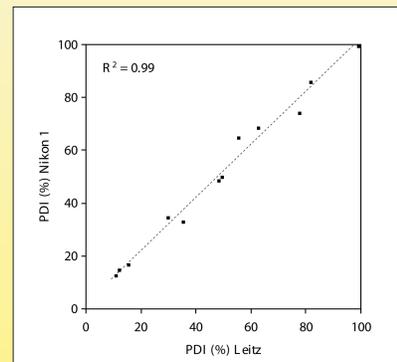


Figure 3. Correlation of calculated PDI values from RGB measurements of filters on Leitz v. Nikon 1 (R² = 0.99)

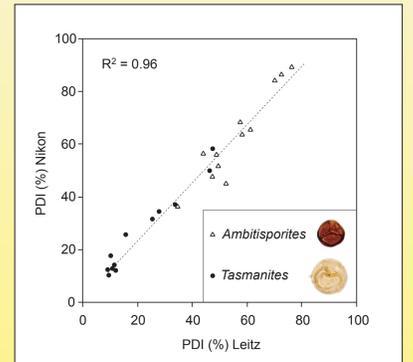


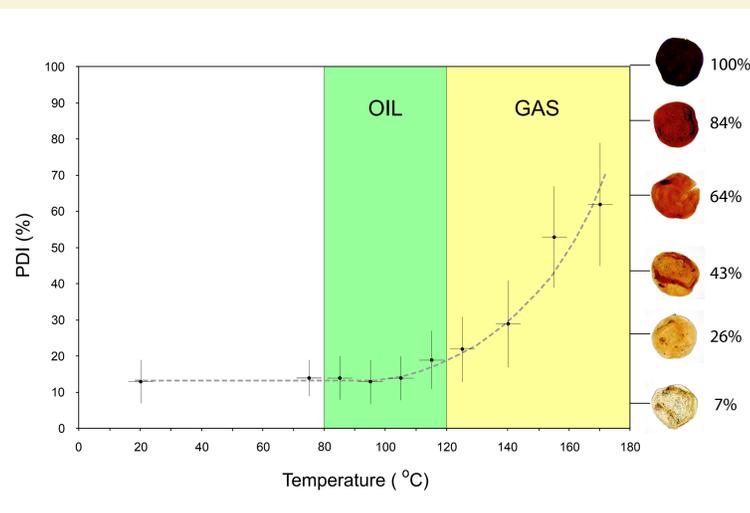
Figure 4. Correlation of calculated PDI values of unoxidised Palaeozoic prasinophytes (*Tasmanites*) and trilete miospores (*Ambitisporites*) on Leitz v. Nikon 1 (R² = 0.96).

RESULTS

EXPERIMENTAL HEATING

Samples of the Lower Permian Tasmanite Oil Shale were heated in a Lenton tube furnace for 100 days in an inert atmosphere (argon) to temperatures between 75°C - 170°C, spanning the oil window. The heated material was then mounted onto glass slides and the PDIs of 50 specimens determined from each sample. The VR of the unheated sample was 0.55% (R_r), equivalent to a peak paleotemperature of ca. 86°C.

Figure 5 Correlation of furnace temperatures and resulting PDI_{Tasmanites} values, with representative specimens shown (RGB measurements on 50 specimens per sample).



The results show a progressive increase in PDI_{Tasmanites} corresponding to gradual darkening with increasing temperature (figure 5).

The high standard deviations for the PDIs obtained represent considerable variation in colour observed within each of the heated populations compared with the unheated population. This may reflect the relatively short experimental heating time (100 days), with some specimens maturing more rapidly than others.

Smaller specimens with a thinner wall tend to be lighter in colour at the same level of thermal maturity. Therefore, size must be taken into account when comparing the PDIs of palynomorphs such as *Tasmanites* which exhibit great variation in diameter.

SUMMARY

Palynomorph Darkness Index (PDI) expresses palynomorph darkness in terms of a single variable which is more intuitive and easier to utilise than colour expressed as separate red, green and blue intensities.

A further advantage of the proposed PDI technique is its use of standard palynological equipment, permitting its application as a low-cost extension of routine palynological investigation.

Excellent correlation can be achieved between PDIs derived from different cameras and microscopes, and photographic filters can be used as a means of calibration.

Almost all unornamented palynomorphs are suitable for determination of PDI but PDI is dependent on wall thickness as well as thermal maturity, so the type of palynomorph used must be specified and its correlation with VR established.

PDI can be used as an alternative indicator of thermal maturity in sections deficient in vitrinite.

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Geoff Clayton is Professor in Geology at Trinity College Dublin. His interests cover palynology, Upper Palaeozoic stratigraphy and palaeogeography, organic maturation, and hydrocarbon source rocks. gclayton@tcd.ie

Robbie Goodhue is Senior Experimental Officer in the Department of Geology, Trinity College Dublin. His interests include thermal maturation, carbon and nitrogen isotopes, and clay crystallinity. goodhuer@tcd.ie



Abigail Rooney is a Ph.D student at Trinity College Dublin. Her research includes experimental thermal maturation and chemical treatment of palynomorphs, and their stable isotope geochemistry. abrooney@tcd.ie

Reference:

GOODHUE, R. and CLAYTON, G., 2010. Palynomorph Darkness Index (PDI) - A new technique for assessing thermal maturity. *Palynology* **34** (2), 147-156.

