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Vitrinite reflectance analysis: minimising the errors

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Vitrinite reflectance is an optical method for assessing the thermal maturity of a rock. The technique was developed by coal petrographers in the 1930's to assess the rank of coal. The method was widely adopted during the 1970's by organic petrologists and organic geochemists as a method for determining the thermal maturity of petroleum source rocks. An accurate determination of thermal maturity is of fundamental importance in basin evaluation as it can be used to bracket episodes of hydrocarbon generation during the burial history of a source bed: revealing whether a rock is in the oil window, gas window, immature or post-mature for hydrocarbon generation. In many geological situations, vitrinite reflectance can be relied upon to make this assessment reasonably accurately. However, there are many examples in the literature where vitrinite reflectance analysis has produced misleading maturity data (Hutton and Cook, 1980; Price and Barker, 1985; Goodarzi *et al.*, 1987). The causes of these misleading data are many. The main purpose of this paper is to discuss the origin of error in vitrinite reflectance analysis, particularly with reference to SE Asian basins, and to suggest ways to minimise the errors.

Vitrinite reflectance analysis is a semi-subjective optical method for determining thermal maturity. It is measured using a high powered reflecting microscope similar to those used in ore microscopy although oil immersion objectives, rather than air, are used. The microscope is fitted with a photometer that is used to measure the amount of light reflected from the surface of a highly polished rock sample. The amount of light reflected is compared to that reflected from the surface of a standard (often sapphire) from which the reflectance of the sample can be calculated.

Vitrinite reflectance analysis is referred to as semi-subjective because although the measurement and calculation are made automatically by the photometer system, the specific part of the sample upon which to make the measurement is selected by the operator.

Vitrinite was selected by organic petrologists as an indicator of thermal maturity because it is the most abundant maceral in coals, generally has an homogenous surface, and shows a uniform, progressive change in physical and chemical properties during its maturation history all the way from peat to meta-anthracite. This progressive change during increasing maturation manifests itself as a continuous increase in reflectance of vitrinite.

Vitinite reflectance has now become so well ingrained in oil and gas exploration that the progress of hydrocarbon generation from a source rock is defined by its vitrinite reflectance. A rock is commonly described as being in the oil window if it has a vitrinite reflectance of between 0.50% and 1.30%. If the vitrinite reflectance is less than 0.50% the source rock is classified as being immature for oil generation. If the reflectance is between 1.30% and 2.00% it is considered to be in the gas window. It is therefore clear that if there are significant errors in vitrinite reflectance data then the relative state of oil and gas generation from a prospective source rock can be seriously misinterpreted. Examples of such occurrences are common in the literature, with the most common phenomena being that of vitrinite reflectance suppression. In such cases, measured reflectance values are anomalously low suggesting the rock is of much lower maturity than it truly is. If such occurrences of suppression are not recognised, poor exploration decisions could result.

The main causes of erroneous vitrinite reflectance data include one or more of the following:

- Preparation procedures.
- Varying vitrinite types and hydrogen enrichment of vitrinite.
- Interference effects of other macerals, sometimes sub-microscopic.
- Impregnation of bitumen or oil.
- Caving and additives.

Clearly, some of these causes are avoidable, bearing in mind the semi-subjective nature of vitrinite reflectance analysis. Of those not avoidable, some are recognisable and the data can be tagged as possibly suppressed. Examples of these causes, and suggestions for their avoidance, are discussed in this paper.

An example of the influence of bitumen impregnation in which a clearly suppressed vitrinite reflectance profile is demonstrated, as well as what is thought to be a representative vitrinite reflectance profile. Let's assume that this well was drilled in a high risk frontier area, and the suppressed data set was unrecognised as suppressed and thought to be valid. The next step in the exercise would likely be regional maturity modelling. In all likelihood, the modelling exercise would be calibrated on available well data as control points. In this example, this would lead not only to erroneous maturity assessments in the kitchen areas but also to erroneous estimation of timing of hydrocarbon generation relative to structure formation.