Scatter in vitrinite reflectance data from coal samples in North Sea wells

TORBJØRN THRONDSEN

Throndsen, T.: Scatter in vitrinite reflectance data from coal samples in North Sea wells. *Norsk Geologisk Tidsskrift*, Vol. 70, pp. 223–228. Oslo 1990. ISSN 0029–196K.

It is not uncommon to observe that vitrinite reflectance results from coal samples with equal maturity and type of vitrinite are distributed over a range of up to 0.20–0.25 %Rm for maturity levels around 0.5 to 1.0 %Rm. It is demonstrated that the variations may be related to microlithotype composition of the samples and accordingly to the depositional environment. A practical consequence is that uncritical interpretation of data may give misleading results. However, improved precision can be obtained by increasing the number of samples, and by considering microlithotype composition.

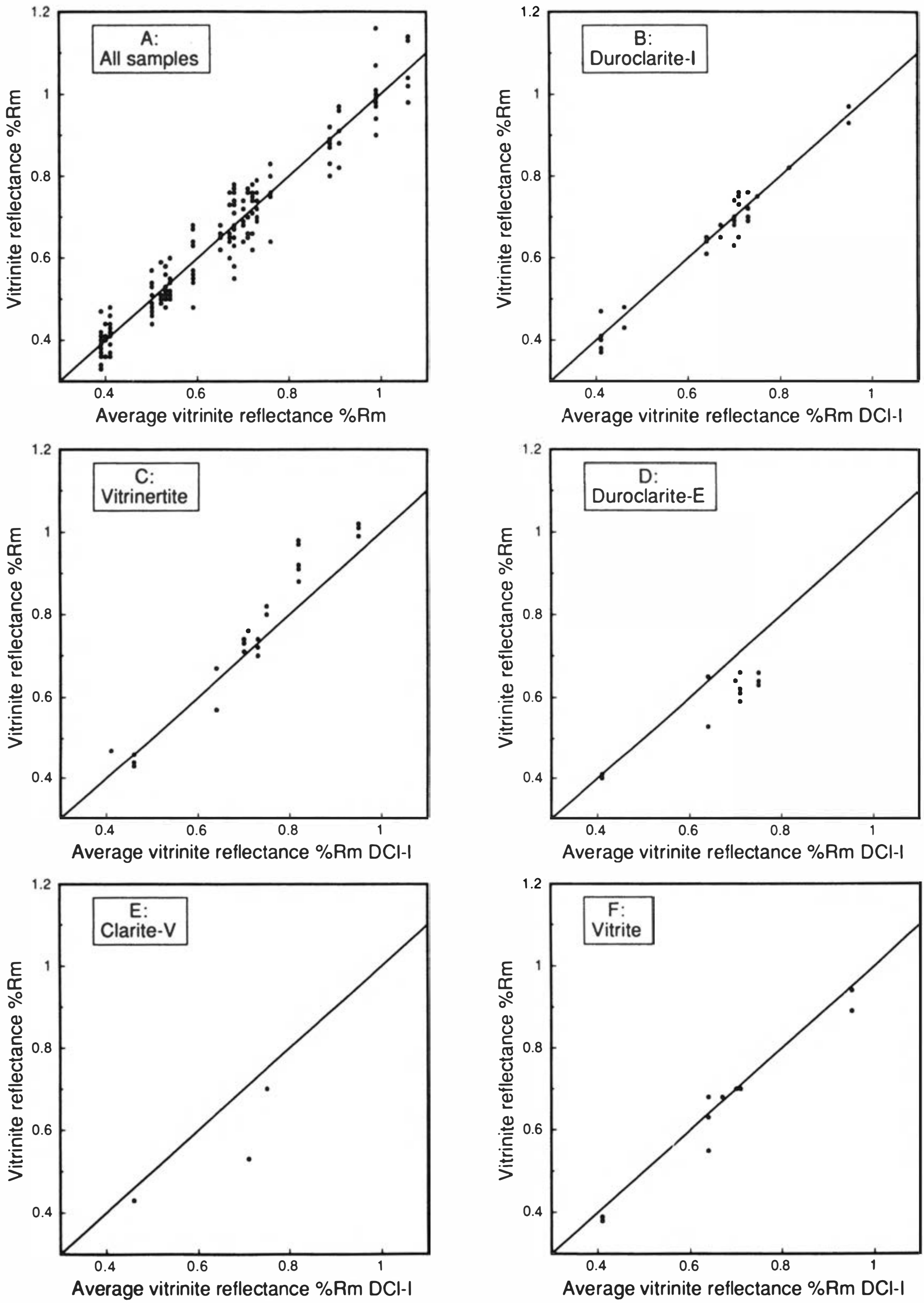
T. Throndsen, Institutt for energiteknikk, P.O. Box 40, N–2007 Kjeller, Norway.

Introduction

The quality of vitrinite reflectance data from clastic sediments has often been questioned due to such factors as uncertain identification of vitrinite, poor particle quality, and variable origin and reflectance properties of material considered to be vitrinite. Such disadvantages are normally non-existent for coaly lithologies. Still, there is frequently an unexpected wide range in measured vitrinite reflectance between coal samples in thin coal-bearing intervals and even between samples in the same coal bed. This has been observed by several previous workers (Table 1), and the range may exceed 0.20 %Rm for maturity levels around 0.5 to 1.0 %Rm.

Table 1. Some published results on the range in vitrinite reflectance between coal samples in the same coal-bearing interval (indicated by *) and between samples in the same coal bed. The data taken from Jones et al. (1972), Durand et al. (1986) and Littke (1987) are taken from text figures and may be subject to minor inaccuracies. Note also that Jones et al. (1972) used a rotating stage technique. Abbreviations used in the table: %Rm = average vitrinite reflectance, Δ%Rm = range in vitrinite reflectance, N = number of samples. Average vitrinite reflectance is the mean of all samples in each interval or coal bed.

	Vitrinite reflectance			Thickness of sample interval
Reference	%Rm	(Δ%Rm)	N	m
Bostick & Foster (1975), Bostick (1986)	0.59	(0.22)	10	45.0*
Durand et al. (1986)	0.53	(0.08)	17	1.3
Fermont (1988)	0.73	(0.19)	10	45.2*
Fermont (1988)	0.81	(0.23)	4	44.2*
Fermont (1988)	1.22	(0.42)	8	51.9*
Jones et al. (1972)	0.63	(0.16)	29	0.3
Jones et al. (1972)	0.67	(0.17)	33	0.3
Jones et al. (1972)	0.99	(0.28)	18	0.9
Jones et al. (1972)	1.05	(0.07)	11	1.3
Littke (1987)	0.65	(0.10)	61	1.2
Littke (1987)	0.72	(0.10)	65	1.3
Littke (1987)	0.87	(0.15)	52	1.0
Littke (1987)	0.91	(0.10)	23	0.5
Littke (1987)	0.95	(0.07)	21	0.4
Littke (1987)	0.97	(0.15)	42	0.8


A:
All samples
Vitrinite reflectance %Rm
Average vitrinite reflectance %Rm
B:
Duroclarite-I
Vitrinite reflectance %Rm
Average vitrinite reflectance %Rm DCI-I
C:
Vitrinertite
Vitrinite reflectance %Rm
Average vitrinite reflectance %Rm DCI-I
D:
Duroclarite-E
Vitrinite reflectance %Rm
Average vitrinite reflectance %Rm DCI-I
E:
Clarite-V
Vitrinite reflectance %Rm
Average vitrinite reflectance %Rm DCI-I
F:
Vitrite
Vitrinite reflectance %Rm
Average vitrinite reflectance %Rm DCI-I

The purpose of this paper is to indicate the precision that can be expected from analysis of coal samples from North Sea wells. It is further demonstrated that the wide variations occasionally seen may be related to microlithotype or maceral composition of the samples and accordingly to the depositional environment.

Material and analytical techniques

The vitrinite reflectance data in the present study were measured on 178 core samples of Jurassic coals from 19 exploration wells in the Norwegian sector of the northern North Sea. All samples were humic coals and typically banded, with vitrinite as the dominant maceral; inertinite was more common than exinite in the majority of the samples. Alginite, which is known to deplete the reflectance of vitrinite (Hutton & Cook 1980; Wolf & Wolff-Fischer 1984), was not present in significant amounts in any of the samples.

The preparation and analytical techniques were standardized for all of the samples. Whole rock samples were embedded in epoxy resin to make briquettes. These were subsequently ground flat and polished. The analytical equipment was a Zeiss MPM 03 photometer microscope equipped with an epiplan-neofluoar 40.0/0.90 oil objective. The sensitive measuring spot was about 2.5 μm in diameter. The measurements were made in oil immersion, through a green band pass filter (546 nm), without a polarizer and using a stationary stage. This procedure is called measurement of random reflectance (%Rm). Davis (1978), Ting (1978), Stach et al. (1982) and Bustin et al. (1985) provide further information on these techniques. A minimum of 50 vitrinite spots were measured in each sample, and the readings were performed exclusively on telocollinite.

Table 2. Range in vitrinite reflectance between samples in the same coal-bearing interval in North Sea wells. Each sample interval is coded for reasons of confidentiality. Abbreviations used in the table: %Rm = average vitrinite reflectance, Δ% Rm = range in vitrinite reflectance, N = number of samples. Average vitrinite reflectance is the mean of all samples in each interval.

Sample interval code	Vitrinite reflectance %Rm	(Δ%Rm)	N	Thickness of sample interval m
A	0.38	(0.08)	10	66.4
B	0.40	(0.08)	9	58.0
C	0.41	(0.12)	11	80.1
D	0.42	(0.12)	6	75.2
E	0.50	(0.13)	11	74.9
F	0.52	(0.10)	5	6.1
G	0.53	(0.10)	13	87.0
H	0.53	(0.10)	7	66.5
I	0.59	(0.20)	10	91.5
J	0.66	(0.06)	6	74.8
K	0.67	(0.16)	6	23.9
L	0.68	(0.23)	11	87.3
M	0.68	(0.08)	6	29.5
N	0.70	(0.10)	6	17.1
O	0.71	(0.12)	5	61.4
P	0.72	(0.16)	10	40.9
Q	0.73	(0.19)	10	91.1
R	0.76	(0.19)	6	71.6
S	0.89	(0.05)	7	67.1
T	0.91	(0.15)	5	53.2
U	0.99	(0.26)	12	54.6

Results and discussion

The results are given in Table 2 and Fig. 1A. Fig. 1A illustrates the distribution of vitrinite reflectance between samples in thin coal-bearing intervals for various levels of average vitrinite reflectance. Average reflectance as indicated by the solid line diagonally across the diagram is the arithmetic mean of all samples in each interval. The intervals are all less than 100 m thick and thus the maturity level within each interval can be assumed to be approximately constant. General experience from North Sea wells is that the increase in vitrinite reflectance with depth for the depths and maturity levels of relevance in this study is less than 0.04 %Rm per 100 m. At least five samples are included from each interval, and each sample displays a narrow gaussian distribution of readings with standard deviations between 0.02 and 0.04 %Rm. The results show

Fig. 1. Distribution of vitrinite reflectance values among coal samples in thin coal-bearing intervals (less than 100 m in thickness) for various levels of average vitrinite reflectance. (A) Vitrinite reflectance for all samples plotted versus average reflectance, i.e. mean of all samples from each coal-bearing interval. The line diagonally across the diagram is the average vitrinite reflectance. (B–F) The samples are classified according to predominant microlithotype, and vitrinite reflectance for individual samples in each coal-bearing interval is plotted versus average reflectance for the duroclarite-I (DCl-I) category samples in each interval. The line diagonally across each diagram is the average of the duroclarite-I samples.

that the difference in vitrinite reflectance between samples from the same coal-bearing interval can be surprisingly wide, up to 0.26 %Rm, and a range between 0.10 and 0.20 %Rm appears to be the rule rather than the exception. Moreover, the range appears to be fairly constant with increasing vitrinite reflectance. These fluctuations are in accordance with observations made by other workers, and they are far too wide to be explained by differences in maturity.

During the sample analysis it became evident that the scatter in vitrinite reflectance to a large extent could be related to differences in the microlithotype or maceral composition of the samples. Stach et al. (1982) and Bustin et al. (1985) give details on definition and classification of microlithotypes (Fig. 2). The relationship between microlithotype composition and vitrinite reflectance properties was studied in 99 samples from 14 of the wells. Each sample was classified using visual estimates according to predominant microlithotype except for samples with more than 95% vitrinite. These were classified according to the second-most important microlithotype. A few samples consisting purely of vitrinite were classified as vitrite. The samples in this study fell into one of the following classes: clarite-V, duroclarite-E, duroclarite-I, vitrinertite and vitrite. The microlithotype composition of a coal is an indicator of the depositional environment, and the categories above reflect according to Stach et al. (1982) a trend of increasing redox potential of the depositional environment when going from clarite-V as one end-member via duroclarite-E and duroclarite-I to vitrinertite as the other. The

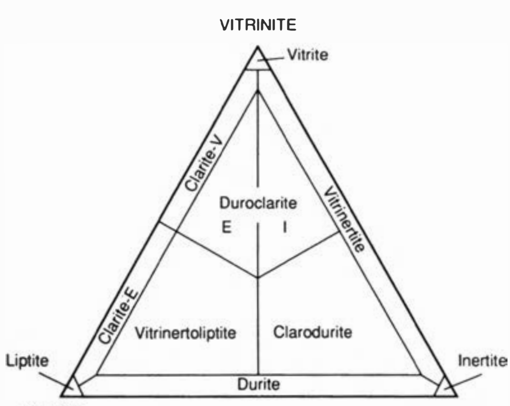


Fig. 2. Diagrammatic representation of microlithotype classification (slightly modified after Bustin et al. 1985).

Table 3. Range in vitrinite reflectance between samples classified according to predominant microlithotype. Abbreviations used in the table: %Rm = average vitrinite reflectance, Δ%Rm = range in vitrinite reflectance, N = number of samples, DCl-I = duroclarite-I, DCl-E = duroclarite-E, VI = vitrinertite, Cl = clarite, V = vitrite. Average vitrinite reflectance is the mean of all duroclarite-I samples in each interval.

Sample interval code	DCl-I %Rm	DCl-I (Δ%Rm)	DCl-I N	DCl-E %Rm	DCl-E (Δ%Rm)	DCl-E N	VI %Rm	VI (Δ%Rm)	VI N	Cl %Rm	Cl (Δ%Rm)	Cl N	V %Rm	V (Δ%Rm)	V N
A	0.41	(0.10)	6	0.40	(0.01)	3	0.47		1				0.39	(0.01)	2
C	0.46	(0.05)	2	0.44	(0.03)	3				0.43		1			
I	0.64	(0.04)	4	0.59	(0.12)	2	0.62	(0.10)	2				0.62	(0.13)	3
M	0.70	(0.06)	4	0.64		1	0.73		1				0.70		1
O	0.70	(0.11)	4				0.72	(0.02)	2						
L	0.71	(0.11)	4	0.62	(0.07)	4	0.76		1	0.53		1	0.70		1
Q	0.73	(0.07)	5				0.72	(0.04)	4				0.79		1
R	0.75		1	0.64	(0.03)	3	0.81	(0.02)	2	0.70		1			
T	0.82		1				0.93	(0.10)	5						
S	0.95	(0.04)	2				1.01	(0.03)	4				0.92	(0.05)	2

vitrite category is in this context ambiguous. The reason is that this category consists solely of a piece of a single band of vitrinite. The relative distribution of the associated exinite and inertinite that possibly exist in the matrix next to the band is unknown. It is therefore impossible to indicate the position of this category along the redox axis. It may in fact belong to any of the other categories.

In Table 3 and Fig. 1B–F the samples are classified according to the scheme given above. In Fig. 1B–F the vitrinite reflectance for individual samples from each coal-bearing interval is plotted versus average vitrinite reflectance. Average vitrinite reflectance as indicated by the solid line diagonally across the diagrams is in this context the mean of all duroclarite-I samples from each interval. Duroclarite-I is chosen as the reference category because it is the only category that is present in all of the intervals, and it is the most common category among the samples in this study. The distributions of data-points in Fig. 1B–F show that the range in reflectance for each microlithotype category is significantly lower than the overall range given in Fig. 1A. The widest range seen for the various categories is 0.11 %Rm which is less than half of the maximum overall range of 0.26 %Rm.

The results in Fig. 1B–F also indicate that there is a link between microlithotype composition and vitrinite reflectance properties. The vitrinite in the vitrinertite category samples has on average the highest reflectance, whereas the reflectance of vitrinite in the duroclarite-I samples is slightly lower. The reflectance of vitrinite in the duroclarite-E and clarite-V category samples is significantly lower, while the vitrite category samples show no clear systematic deviation.

The results above support the statements of Stach et al. (1982) and Littke (1987) that the depositional environment is a main factor controlling the scatter in vitrinite reflectance and that the reflectance increases with increasing redox potential.

Conclusion

The results of this study on North Sea coals confirm that surprisingly wide differences in reflectance which cannot be related to differences in maturity or vitrinite type may occur between coal samples. Differences between samples of up to 0.20–0.25 %Rm is not uncommon for maturity levels around 0.5 to 1.0 %Rm and, moreover, a range wider than 0.10 %Rm appears to be the rule rather than the exception. The scatter, however, can be related to microlithotype composition and consequently to the depositional environment. The scatter within each microlithotype category is much lower than the overall scatter.

A practical consequence is that coal is still a preferred type of lithology for vitrinite reflectance analysis giving unambiguous and narrow distributions of measurements. However, maturity interpretations based on only one or a few samples may give imprecise results. Precise determinations, on the other hand, can be obtained by increasing the number of samples in order to fill up a scatter range of approximately 0.25 %Rm and take the median as the correct value. The precision can be further improved by taking microlithotype or maceral composition into account. A rough estimate of the predominant microlithotype is very simple and can be made simultaneously with the vitrinite reflectance measurements with little extra investment of time.

Acknowledgements. – Statoil is acknowledged for providing samples, financial support and permission to publish the results. Thanks also to Lars Kirksæther, who prepared the samples to a very high standard and to Euan Mearns, who kindly read through the manuscript and corrected the English.

Manuscript received July 1990

References

Bostick, N. H. & Foster, J. N. 1975: Comparison of vitrinite reflectance in coal seams and in kerogen of sandstones, shales and limestone in the same part of a sedimentary section. *In* Alpern, B. (ed.): *Pétrographie de la matière organique des sédiments, relations avec la paléotempérature et le potentiel pétrolier*, 13–25. Centre National de la Recherche Scientifique, Paris.

Bostick, N. H. 1986: Notes from the laboratory. *Newsletter of the Society for Organic Petrology 3(2)*, 6–7.

Bustin, R. M., Cameron, A. R., Grieve, D. A. & Kalkreuth, W. D. 1985: *Coal Petrology its Principles, Methods and Application, Short Course Notes*, vol. 3, 2nd ed. 230 pp. Geological Association of Canada.

Davis, A. 1978: The reflectance of coal. *In* Karr, C. (ed.): *Analytical Methods for Coal and Coal Products*, vol. 1, 27–81. Academic Press, New York.

Durand, B., Alpern, B., Pittion, J. L. & Pradier, B. 1986: Reflectance of vitrinite as a control of thermal history of sediments. *In* Burrus, J. (ed.): *Thermal Modeling in Sedimentary Basins*, 441–474. Édition Technip, Paris.

Fermont, J. J. M. 1988: Possible causes of abnormal vitrinite reflectance values in paralic deposits of the Carboniferous in the Achterhoek area, The Netherlands. *Organic Geochemistry 12*, 401–411.

Hutton, A. C. & Cook, A. C. 1980: Influence of alginite on the reflectance of vitrinite from Joadja, NSW, and some other coals and oil shales containing alginite. *Fuel 59*, 711–714.

Jones, J. M., Murchison, D. G. & Saleh, S. A. 1972: Variation in vitrinite reflectivity in relation to lithology. *In* von Gaertner, H. R. & Wehner, H. (eds.): *Advances in Organic Geochemistry 1971*, 601–612. Pergamon Press, Oxford.

Littke, R. 1987: Petrology and genesis of Upper Carboniferous seams from the Ruhr region, West Germany. *International Journal of Coal Geology 7*, 147–184.

Stach, E., Mackowsky, M. T., Teichmüller, M., Taylor, G. H., Chandra, D. & Teichmüller, R. 1982: *Stach's Textbook of Coal Petrology*, 3rd ed. 535 pp. Gebruder Borntraeger, Berlin.

Ting, F. T. C. 1978: Petrographic techniques in coal analysis. *In* Karr, C. (ed.): *Analytical Methods for Coal and Coal Products*, vol. 1, 3–26. Academic Press, New York.

Wolf, M. & Wolff-Fischer, E. 1984: Alginit in humuskohlen karbonischen Alters und sein Einfluss auf die optischen Eigenschaften des begleitenden Vitrinits. *Glückauf-Forschungshefte 45*, 243–246.