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VITRINITE REFLECTANCE STUDIES OF DISPERSED ORGANIC MATERIAL FROM NORTHLAND ALLOCHTHON ROCKS, NORTH ISLAND, NEW ZEALAND

*N. AADIL and G.M.D. SOHAIL

Department of Geological Engineering, University of Engineering and Technology, Lahore, Pakistan

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The Northland Allochthon is a structurally displaced rock unit located between Three Kings Island and Mt. Camel in northern North Island, New Zealand. Lithologically, the allochthonous unit is composed of different lithofacies comprising sandstone, siltstone, greensand, siliceous mudstone, argillaceous micritic limestone and rare coal measures alongwith dispersed organic matter. In this paper, vitrinite reflectance of dispersed organic matter in non-coaly clastic rocks from different lithofacies of Northland Allochthon, Rocks, North Island, New Zealand is analyzed to assess the degree of diagenesis of organic matter and paleo temperature. Vitrinite Reflectance values range from 0.30 to 2.00 %Rm and correspond to estimate of palaeotemperature of 60° to 180°C. Oldest sedimentary complex may have been affected by heating to 300°C from intrusion of keratophyre dykes.

Keywords: Northland Allochthon, Dispersed organic matter, Vitrinite reflectance, Palaeo temperature, Keratophyre dykes

1. Introduction

The average content of organic matter in sedimentary rocks is about 15–20 kg/m^3; the total mass in the continental sector of the sedimentary crust (continents and shelves) is as high as 10^{16} tons. Organic matter is the source of petroleum and fuel gases. The organic matter is usually a component of sedimentary material even if it is present in low abundance (usually lower than 1%). Most of the organic matter is found in the sedimentary rocks as clastic mineral grains (90%). The most of the solid organic matter in sedimentary rocks is about three hundred times than that of coal. It is almost 0.1 - 1 % by weight of the siltstone and sandstone; less abundant in limestone and almost absent in pure limestone. Shale has the maximum percentage of solid organic matter (1-10%). Oil shale, carbonaceous shale and coal are even richer [1-3].

Vitrinite reflectance studies on dispersed organic material in sediments have been conducted over the past several years [4, 5, 6]. Vitrinite is one of the most widely used, precise and reliable techniques for estimating organic diagenesis. This technique is applicable to most sedimentary rocks except coarse grained, permeable rocks in which percolation of oxygenated ground water may have led to oxidation of the vitrinite. Fine dispersed organic matter in the clastic rocks is used for vitrinite reflectance measurements after concentration by demineralization using acid or heavy liquid treatment. Further, Vitrinite reflectance is commonly used to assess the rank of organic matter in the rocks [7].

In this paper, eighteen samples of dispersed organic matter in different lithofacies of Northland Allochthon rocks are studied to find out the degree of diagenesis of organic matter and paleo temperature by reflectance analysis of vitrinite in non-coaly clastic rocks. Organic maturation is an indicator of the maximum temperature to which the organic matter has been subjected to heat during burial.

2. Study Area

The Northland Allochthon is located between the Three Kings Island and Mt. Camel (Figure 1) as a structural high in northern North Island of New Zealand. This is a thick widespread displaced rock unit containing rocks of Late Cretaceous to Early Miocene age [8]. The Northland Allochthon is estimated to have a present day volume of 32000Km^3. Lithologically the allochthonous rocks are mostly composed of sandstone, siltstone, green sand, siliceous mudstone, argillaceous micritic limestone and rare coal measures alongwith dispersed organic matter. It overlies the autochthonous, paleogene non-marine to marine transgressive sediments. It is unconformably overlain by the Waitemata and correlative groups of Upper Oligocene-Lower Miocene age [9].

3. Methodology

Field rock samples were grounded to powder using mortar and pestle for kerogen separation by demineralization with hydrochloric and hydrofluoric acids and heavy liquid treatment. The kerogen was washed with distilled water and centrifuged a minimum of four time to reduce the acid residue. After drying at

* Corresponding author : naseemaadil90@gmail.com

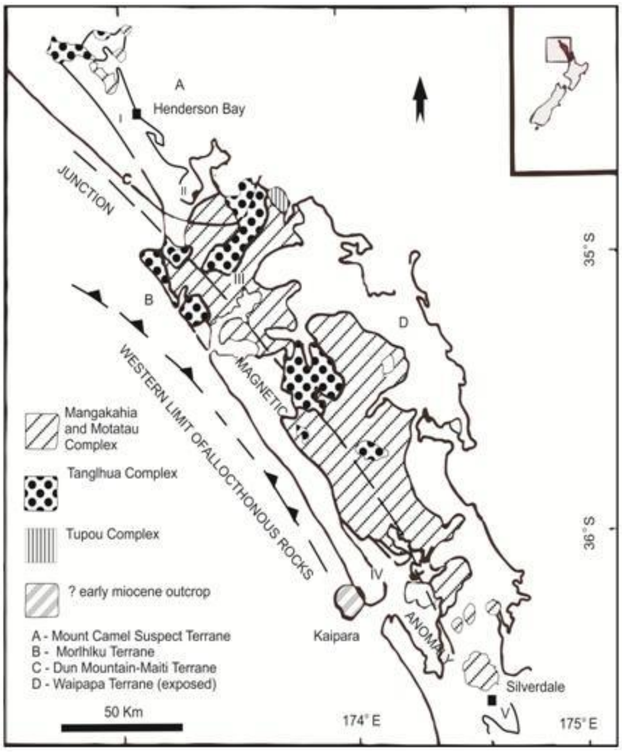

Figure 1. Outcrop distribution of the Northland Allochthon rocks and inferred basement terrane in Northland, New Zealand (after Isaac et al. 1974).

room temperature, separated kerogen grains were mounted in an epoxy-resin plastic mould. The specimen surface was ground on a rotating lap with progressively finer silicon carbide and then polished in two stages with 1.0 and 0.05 micron aluminium oxide powder on textmet. This was followed by final polishing on microcloth using the 0.05 micron aluminium oxide powder. The samples were then dried with filter paper and put in the desiccators overnight prior to the measurement.

The polished kerogen samples were used to obtain the vitrinite reflectance with a Leitz reflected light microscope equipped with stabilized xenon light source, photometer and digital voltmeter for recording. A narrow band filter (546nm) was placed between the objective lens and photometer. An aperture diaphragm was adjusted to restrict the area of measurement to one micron. A 50 x 10.85 oil immersion lens and an optovar setting of 1.25 were used to obtain the maximum magnification of 500x. The photometer was calibrated after every 20-minutes to correct for instrument drift using the glass prisms with reflectance of 0.54% and 1.24% Ro (Leitz standard 196) in an immersion oil of Ne = 1.5180. To obtain a representative result, the sample was moved on the microscope stage with a line to line distance of 1 mm or 2 mm depending upon the frequency of the grains and finally mean reflectance values (%Rm) was calculated for each sample.

4. Results

The following three maceral groups of organic matter were identified and classified on the basis of relative reflectance, colour, morphology etc. [10]. The macerals with the lowest reflectance i.e. liptinite (Plate B) and highest reflectance i.e. Fusinite are usually minor constituents from the samples and those with intermediate reflectance (Vitrinite) make the dominant part.

Vitrinite macerals are derived from the cell wall material or the woody tissues of plants. The low and high grey vitrinite group is separated from similar macerals to designate those particles whose rank represents the maturation within host rock (Plate-A). The macerals in the samples consists of debris having diverse origin and different history of transportation. Some eroded from older rocks and part of their present rank was attained in the former host rock. Some vitrinite may be plant fragments, fresh altered filled with humic compounds and some have been biochemically altered during the complicated history of trip from plant to site of final deposition. Some high grey grains are vitrinite and some are redeposited from older rock. Some may be plant or peat material which is biochemically altered before it is incorporated into sediments.

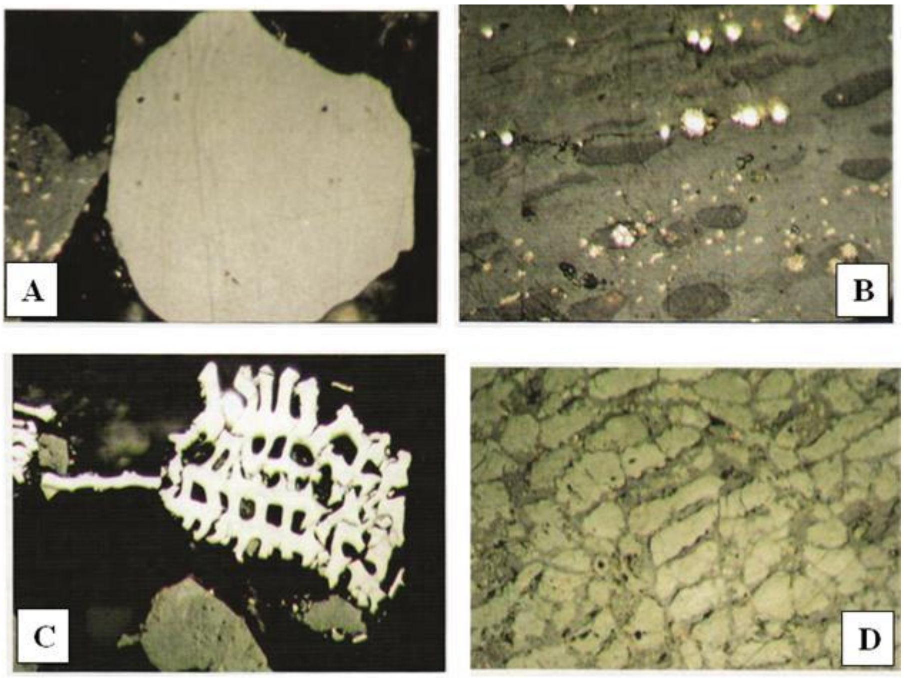

Figure 2. Plate: Maceral groups of solid organic matter identified and classified on the basis of relative reflectance, colour, and morphology. (A) Vitrinite from Matukaraka Facies with 0.83%Ro; (B) Liptinite from lignite samples with 0.42%Ro;(C) Fusinite from Matukaraka Facies and (D) Waipawa Black Shale with 0.46%Ro.

Liptinite are derived from the waxy and resin parts of the plants and includes plant spores and pollens recognisable from their forms, resin particle or cell fillings, irregular fragments of plant cuticle, algal remains and probably some solid bitumen or other secondary matter (Plate-B & D). These are dull grey in polished surface but appear yellow or yellow grey in transmitted light. Floccules or irregular masses or fine grained groundmass are difficult to polish for reflectance measurements. These are mainly algal debris plus finely comminuted liptinite and other macerals. They appear as the lightest material in transmitted light.

Inertinite macerals characterize higher reflectance than the corresponding vitrinite of the same rank. They are usually derived from plant material that has been strongly altered and degraded in the post stage of coal formation. This group may contain semi-fusinite, fusinite (Plate C), micrinite or Sclerotinite macerals.

5. Discussion and Conclusions

Vitrinite reflectance is used successfully in the non coal bearing sequences as a rank parameter of burial metamorphic history. Interpretation of the reflectance data depends on sound petrographic analysis and also on knowledge of lithology and depositional environment to help sort out the disturbing influences of oxidation, bioturbation, and reworking of the second-cycle material. Because there is an inherent scatter in the mean reflectance data, a sequence of samples is needed to calculate the average reflectivity.

Results of mean reflectance values of dispersed organic matter different lithofacies of the Northland Allochthon, North Island, New Zealand is shown in Table 1. A histogram of mean reflectance values shows moderate level of maturity (0.8 to 1.50%Rm, Figure 3).

Samples of the Tokerau Clastic sediments (Mt. Camel Suspect Terrane) from Henderson beach locality contain sufficient vitrinite for reflectance analysis. Histogram (Figure 3) of mean vitrinite reflectance shows a variable thermal maturity from 0.72% to 2.72%. Some grains have mean vitrinite reflectance values more than 2.5% which, according to Robert, 1988 [8] correspond to a paleo temperature upto 300°C.

Samples from Matukaraka, Punakitere and Awapoko facies are not typically high in rank. Seven samples analyzed show moderate level of thermal maturity (%R_{max}=1.6). A few samples maintain maturation level below 0.6% and as high as 2.4%. They seem to be very uniform throughout Cretaceous period. A general trend of increasing thermal maturity from north to south can be observed from samples at Hokianga Harbour, Kaipara Harbour and Whangaporoa road sections. This trend does not correspond with the values from the Tokerau Clastic at Henderson bay which is because of keratophyre dyke in the area.

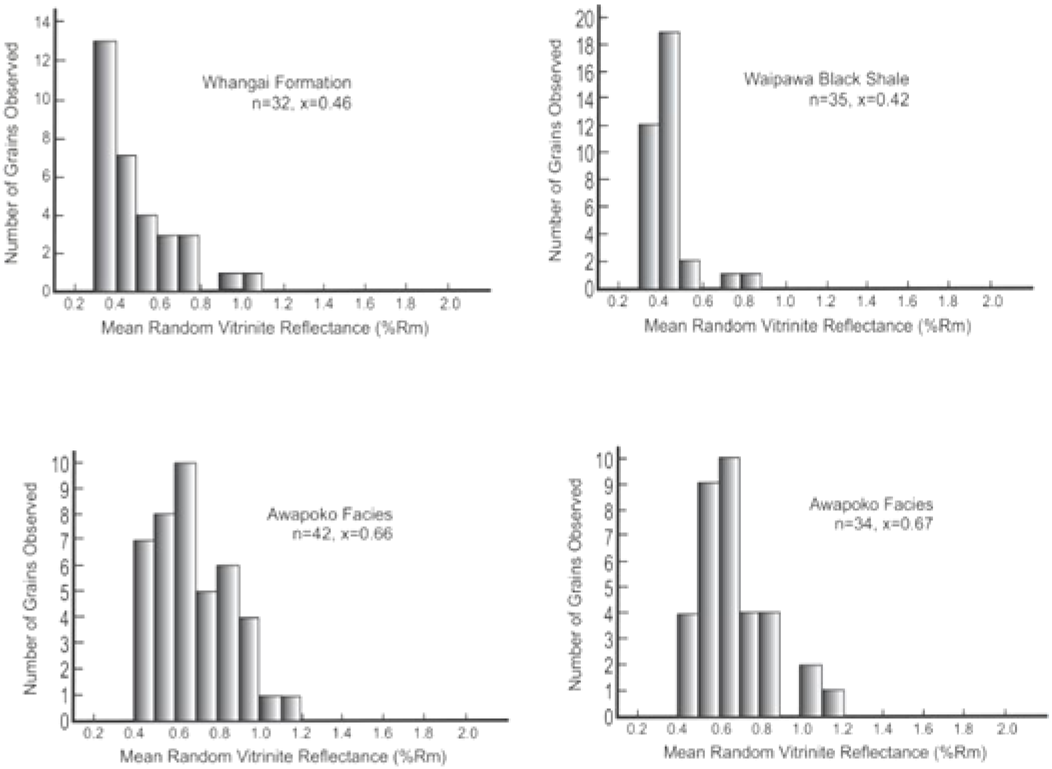

Figure 3. Histograms of mean reflectance values of dispersed organic matter different lithofacies of the Northland Allochthon, North Island, New Zealand.

Table 1. Mean reflectance values of dispersed organic matter different lithofacies of the Northland Allochthon, North Island, New Zealand

Sample	Lithofacies	Age	%Rmin	%Rmax	n	δ	%Rm
AU46203	Tokerau Clastics	?Cm	0.53	2.43	32	0.22	1.43
AU46213	Matukaraka	Cn - Rm	0.46	1.45	40	0.2	0.88
AU46214	Matukaraka	Cn - Rm	0.45	1.85	20	0.3	1.1
AU46210	Matukaraka	Cn - Rm	0.7	1.79	34	0.32	0.92
AU46187	Matukaraka	Cn - Rm	0.48	1.89	38	0.4	0.95
AU46189	Matukaraka	Cn - Rm	0.6	1.4	38	0.12	1.15
AU46197	Matukaraka	Cn - Rm	0.4	1.94	38	0.46	0.95
AU46199	Matukaraka	Cn - Rm	0.42	1.57	38	0.3	0.83
AU46200	Matukaraka	Cn - Rm	0.4	1.72	36	0.35	0.87
AU46182	Punakitere	?Cn - >Mh	0.3	0.56	35	0.06	0.42
AU46181	Punakitere	?Cn - >Mh	0.4	0.61	35	0.05	0.4
AU46172	Awapoko	Ra - ?Mh	0.58	1.79	35	0.23	0.87
AU46175	Awapoko	Ra - ?Mh	0.52	1.72	33	0.61	1.35
AU46176	Awapoko	Ra - ?Mh	0.6	1.11	34	0.17	1.02
AU46178	Awapoko	Ra - ?Mh	0.4	0.97	35	0.18	1.25
AU46170	Whangai	Mh - Dt	0.45	0.95	32	0.16	0.46
AU46167	Waipawa B. Shale	Dt	0.4	0.85	35	0.09	0.42
AU46168	Waipawa B. Shale	Dt	0.5	0.79	35	0.12	0.46

In Whangai Formation and Blackpawa Shale, the average mean vitrinite reflectance values range from 0.65-0.75 %Rm which correspond to an paleotemperature of 90-110°C.

The average reflectance is 0.60 to 0.90 percent, which according to our calibration falls within the subbituminous A to high volatile C bituminous coal rank.

Exposure of coal or dispersed organic matter to heating by igneous activity, atmosphere, oxygenated water in the subsurface results in the oxidation of organic and inorganic constituents. The characteristics of the oxidised coal vary the temperature of the oxidation and local oxidising conditions. Although all macerals are susceptible to oxidation but vitrinite shows greater evidence of oxidation than inertinite or liptinite. Oxidation results in the formation of microspores, microfissures, and oxidation rims on the macerals (Plate D).

The evolution of dispersed organic matter in sedimentary rocks with increasing burial and temperature is studied from peat stage through the stages of lignite, sub-bituminous coal, bituminous coal, anthracite and meta-anthracite to the stages of semi-graphite [9, 10]. The vitrinite reflectance increases progressively with increasing rank from 0.25-0.3 to 10-17% for graphite. In the Northland Allochthon rocks, the rank of the dispersed organic matter fall in between lignite and semi-anthracite, based on the vitrinite reflectance results and have diagenesis to catagenesis phases [11].

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