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VITRINITE REFLECTANCE AND GEOHISTORY ANALYSIS OF VOLUTA NO. 1 WELL, OTWAY BASIN

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SUMMARY

Vitrinite reflectance of 16 samples from the Otway Basin Voluta No. 1 well has been measured. These measurements indicate the Otway Group to be in the condensate/wet gas zone and the Sherbrook Group to be in the oil generation zone. Younger sediments are immature. A geothermal gradient of 30^{o}C/km for the last 130 million years is consistent with the observed vitrinite reflectance data from the well. Geohistory analysis of the well indicates the Otway Group entered the oil generation zone about 90 million years ago, and the Sherbrook Group entered the oil generation zone some 75 million years ago.

1. INTRODUCTION

As a continuing study of the coalification and hydrocarbon maturation process, a detailed study of coal rank variation in the off-shore petroleum exploration well Voluta No. 1 in the Otway Basin was undertaken (figure 1). Reflectance of vitrinite in oil (Ro) was used as the index of coal rank. Samples of cores and cuttings from Voluta 1 were supplied by the Bureau of Mineral Resources, Canberra. Eight core chips and eight ditch cuttings were analysed; the depths sampled are shown in Table 1.

Vitrinite reflectance can be related to the thermal and subsidence history (geohistory) of a sedimentary basin (Falvey and Middleton, 1981). A computer program, which reconstructs the depositional history of a sedimentary section given present day stratigraphic data, was obtained from Dr. D.A. Falvey of the Department of Geology and Geophysics at the University of Sydney. The program also calculates the increase of vitrinite reflectance with time, and plots calculated present day reflectance against observed reflectance. A simple thermal model explaining the Voluta 1 reflectance data is presented.

2. EXPERIMENTAL METHOD AND RESULTS

The ditch cuttings and core chips were crushed to -1 millimetre. The crushed samples were mounted in a cold setting polyester resin, ground and polished. Reflectance analyses were carried out on the polished grain mounts with a Zeiss Universal Polarizing Microscope/MPM03 Microscope Photometer using a X40 oil immersion objective at a wavelength of 546 nanometres. The measuring stop diameter was 2 microns. The refractive index (R.I.) of the oil was 1.518.

Measurements were made on total vitrinite and some transitional material. The number of readings taken, the standard deviation and average reflectance, $\bar{R}o(\%)$, are given in Table 1. Reflectrograms of the 16 samples are presented in Figure 2 (a-c).

3. GEOLOGY

3.1 Stratigraphy of the Otway Basin

Known Jurassic to Tertiary sediments in the Otway Basin are divided into five Groups. The basal Jurassic to Lower Cretaceous Otway Group consists of continental sandstones and interbedded shales. The overlying Upper Cretaceous Sherbrook Group sediments show a transgressive - regressive cycle including 1570 m of marine siltstones in Voluta 1 (Ellenor, 1976). The Paleocene Wangerrip Group is generally much thinner than the Sherbrook Group, but exhibits a similar transgressive - regressive cycle. The Eocene Nirranda Group unconformably overlies the Wangerrip Group; the sediments of this group indicate a marginal marine environment. The uppermost Middle Oligocene to Pliocene Heytesbury Group consists of biogenic limestones and marl.

3.2 Stratigraphy of Voluta No. 1

The present day stratigraphy of Voluta No. 1 is shown graphically in Figure 3 as the depth section for a time of zero (right-hand-side of the geohistory plot). The Eocene Nirranda Group was not encountered in the Voluta 1 well. The large duration of non-deposition between the Paleocene Wangerrip Group and the Upper Tertiary Heytesbury Group is due to a slow onset of low magnitude subsidence after the rifting and continental breakup of Australia and Antarctica about 55 million years ago. The total depth of the well is 3848 m subsea or 3974 m below the rotary table of the drilling platform.

3.3 Present Day Heat Flow in Voluta No. 1

Nicholas et al (1980) have tabulated uncorrected geothermal gradients in various wells in Australian sedimentary basins. They give the uncorrected geothermal gradient in Voluta 1 to be 24.58^{o}C/km with a mean annual seabed temperature of 13^{o}C; the uncorrected bottom-hole temperature of Voluta 1 is 107.6^{o}C. Middleton (1979) has shown true formation temperature to be some 20^{o}C greater than the bottomhole temperature. Therefore, the corrected geothermal gradient is approximately 30^{o}C/km. If a typical sedimentary thermal conductivity of 5×10^{-3} cal cm^{-1} sec^{-1} ^{o}C^{-1} is assumed, the present day heat flow in Voluta is 1.5 HFU (heat flow unit: 10^{-6} cal cm^{-2} sec^{-1}).

4. GEOHISTORY AND REFLECTANCE MODELLING

Van Hinte (1978) explained a method of performing a geohistory analysis (geological burial history) from observed stratigraphic well data. Falvey and Middleton (1981) have described a computerized method of geohistory analysis. This method determines vitrinite reflectance variation with time in conjunction with the geohistory subsidence plot. The vitrinite reflectance variation with time is based on the equation:-

$$(\bar{R}o)^a = A \int_0^t \exp\,[bT(t^1)]\;dt^1 \qquad , \qquad (1)$$

where $\bar{R}o$ is average vitrinite reflectance, t is time, T(t) is temperature as a function of time, and a, A and b are constants; a = 5.5, $A = 2.8 \times 10^{-6}$ and b = 0.069.

The geohistory analysis of Voluta 1 is shown in Figure 3. The four geological Groups are distinguished, and the time variation of various 'critical' vitrinite reflectance values (0.5, 0.6, 0.8, 1.0, 1.3 and 1.6 percent) are shown. A uniform heat flow of 1.5 HFU is assumed to have persisted over the last 130 million years. Vitrinite reflectance from (1) is calculated on the basis of this assumed simple thermal history. Figure 4 shows the theoretical present day vitrinite reflectance versus depth profile compared with the measured data from Table 1. A good concordance of theory with observation is obtained.

5. CONCLUSION

Observed vitrinite reflectance measurements from the Otway Basin off-shore well Voluta 1 suggest a heat flow in the region of approximately 1.5 HFU, that is a geothermal gradient of some 30^{o}C/km. The Otway Group is in the condensate/wet gas zone ($\bar{R}o$ > 1.3%). The Wangerrip and Heytesbury groups are in the immature zone ($\bar{R}o$ < 0.5%). The Sherbrook Group is presently in the oil generation zone (0.5% < $\bar{R}o$ < 1.3%; Shibaoka et al., 1973). The present coalification model, equation (1), adequately explains observed vitrinite reflectance in Voluta 1. Reference to the geohistory analysis (Fig. 3) indicates the base of the Otway Group entered the oil generation zone ($\bar{R}_o$= 0.5%) about 90 million years ago, and the top of the Group (equivalent to the base of the Sherbrook Group) entered the zone about 77 million years ago. The base of the Otway Group entered the condensate/wet gas zone ($\bar{R}o$ = 1.3%) about 45 million years ago. The upper part of the Sherbrook Group has not yet entered the oil generation zone.

6. REFERENCES

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TABLE 1. Measured mean reflectance of vitrinite in oil of coal and carbonaceous shale samples from Voluta 1.

TYPE OF SAMPLE	DEPTH (m)	SAMPLE NO.	NO. OF READINGS	STANDARD DEVIATION	Ro(%) average
ditch cutting	865.6 - 868.7	33457	70	0.04	0.37
ditch cutting	893.1 - 896.1	33455	46	0.04	0.40
ditch cutting	1002.8 -1005.8	33456	40	0.06	0.44
ditch cutting	1557.5 -1560.6	33458	55	0.05	0.45
ditch cutting	1688.6 -1691.6	33459	58	0.05	0.48
ditch cutting	2529.8 -2535.9	33460	35	0.22	0.99
ditch cutting	3203.4 -3206.5	33461	56	0.20	0.92
ditch cutting	3956.3 -3959.4	33462	60	0.11	1.38
core chip	908.6	33463	30	0.14	0.24
core chip	1670.3	33465	62	0.05	0.44
core chip	1796.3	33464	20	0.18	0.55
core chip	2163.2	33466	72	0.17	0.66
core chip	2319.2	33467	63	0.15	0.72
core chip	2461.6	33468	25	0.26	0.92
core chip	3510.0	33470	5	0.24	0.96
core chip	3511.0	33469	42	0.27	0.92

Figure 1. Location of the petroleum exploration well Voluta No. 1.

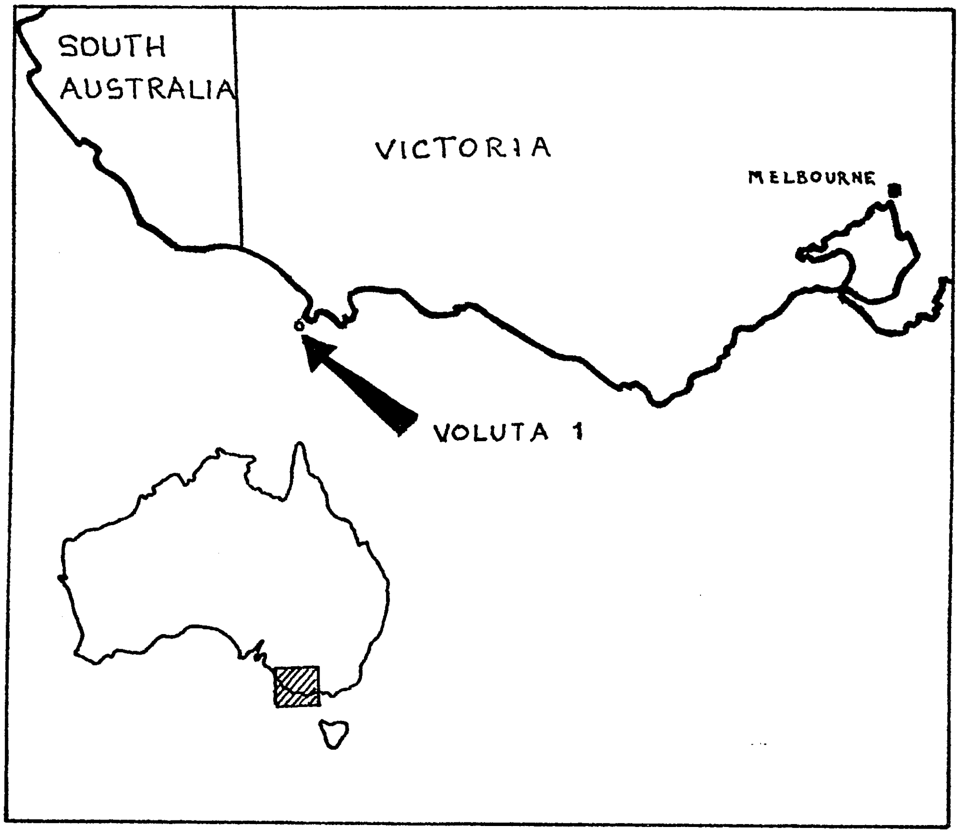

Figure 2(a) Voluta 1 Reflectograms

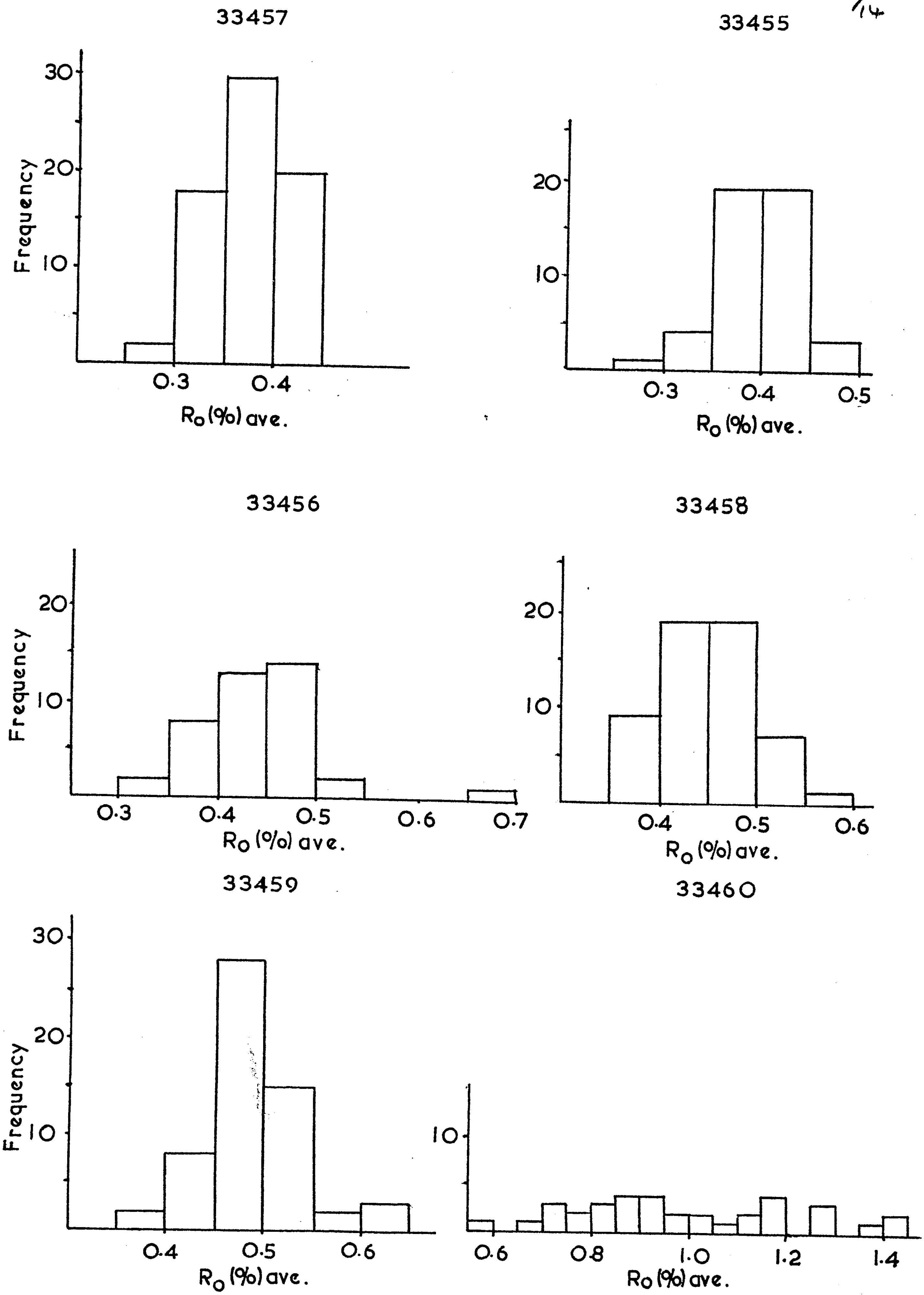

Figure 2(b) Voluta 1 Reflectograms

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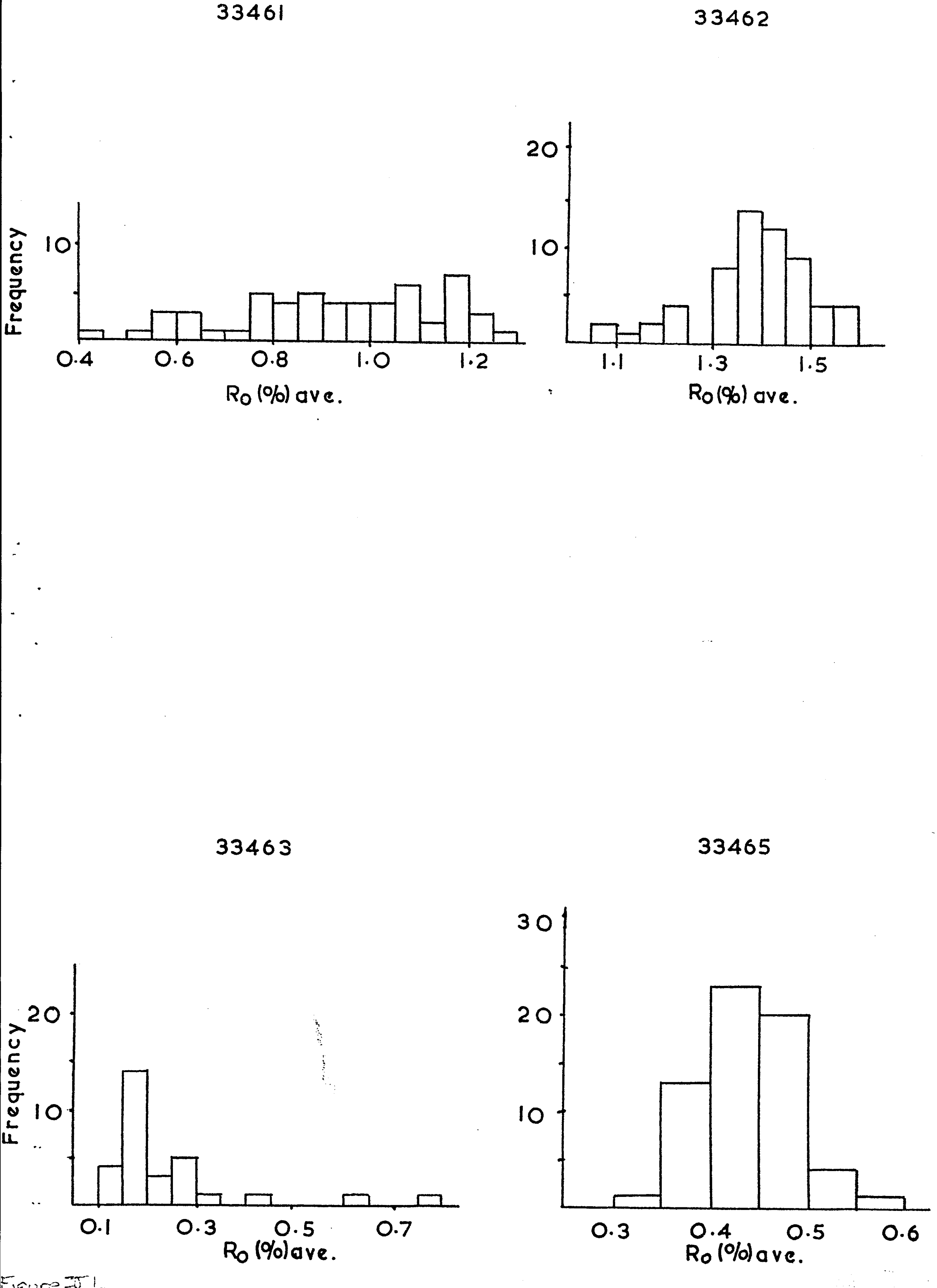

Figure 2b

Figure 2(c) Voluta 1 Reflectograms

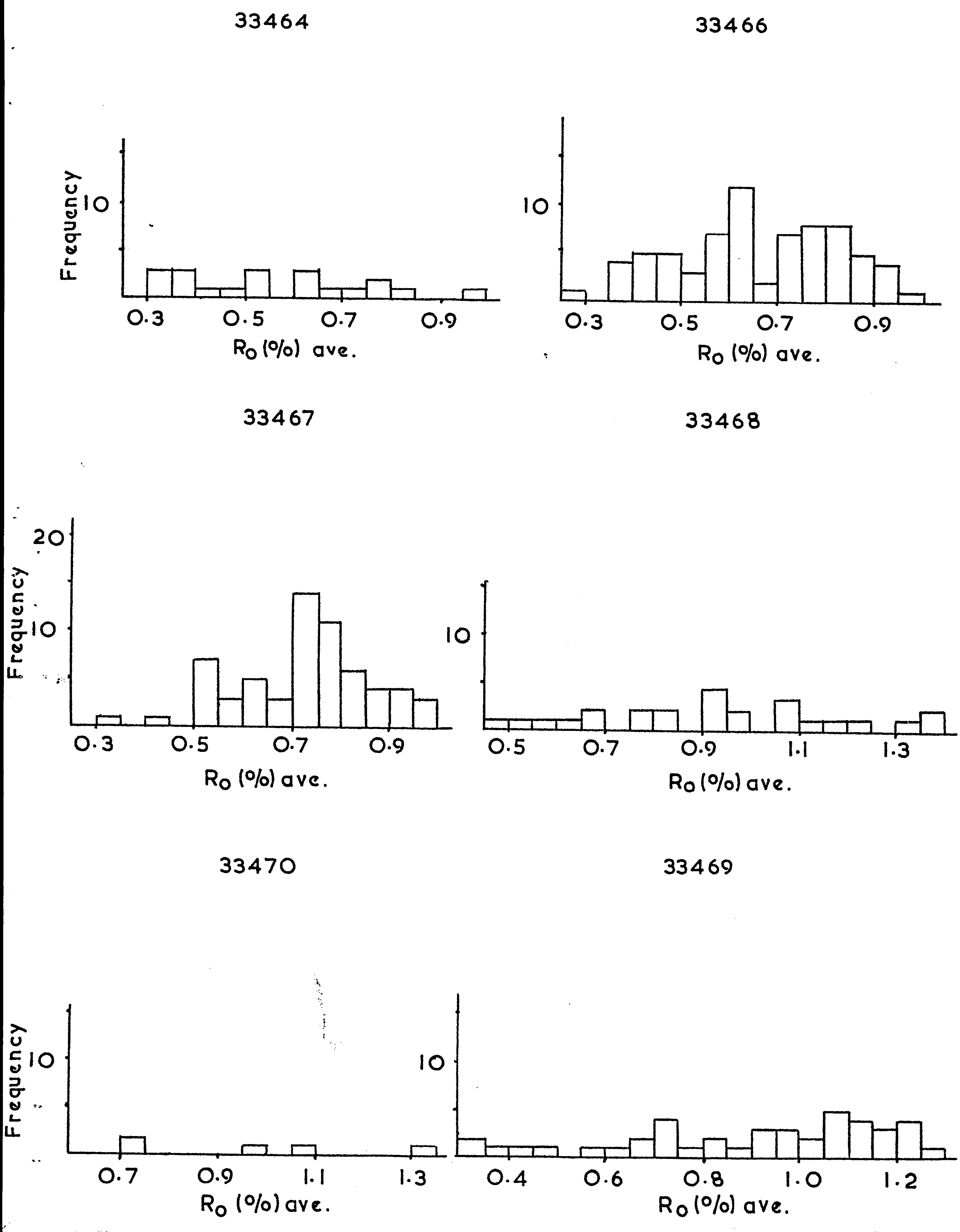

Figure 2 c

Figure 3. Geohistory and vitrinite reflectance analyses of the Voluta 1 well

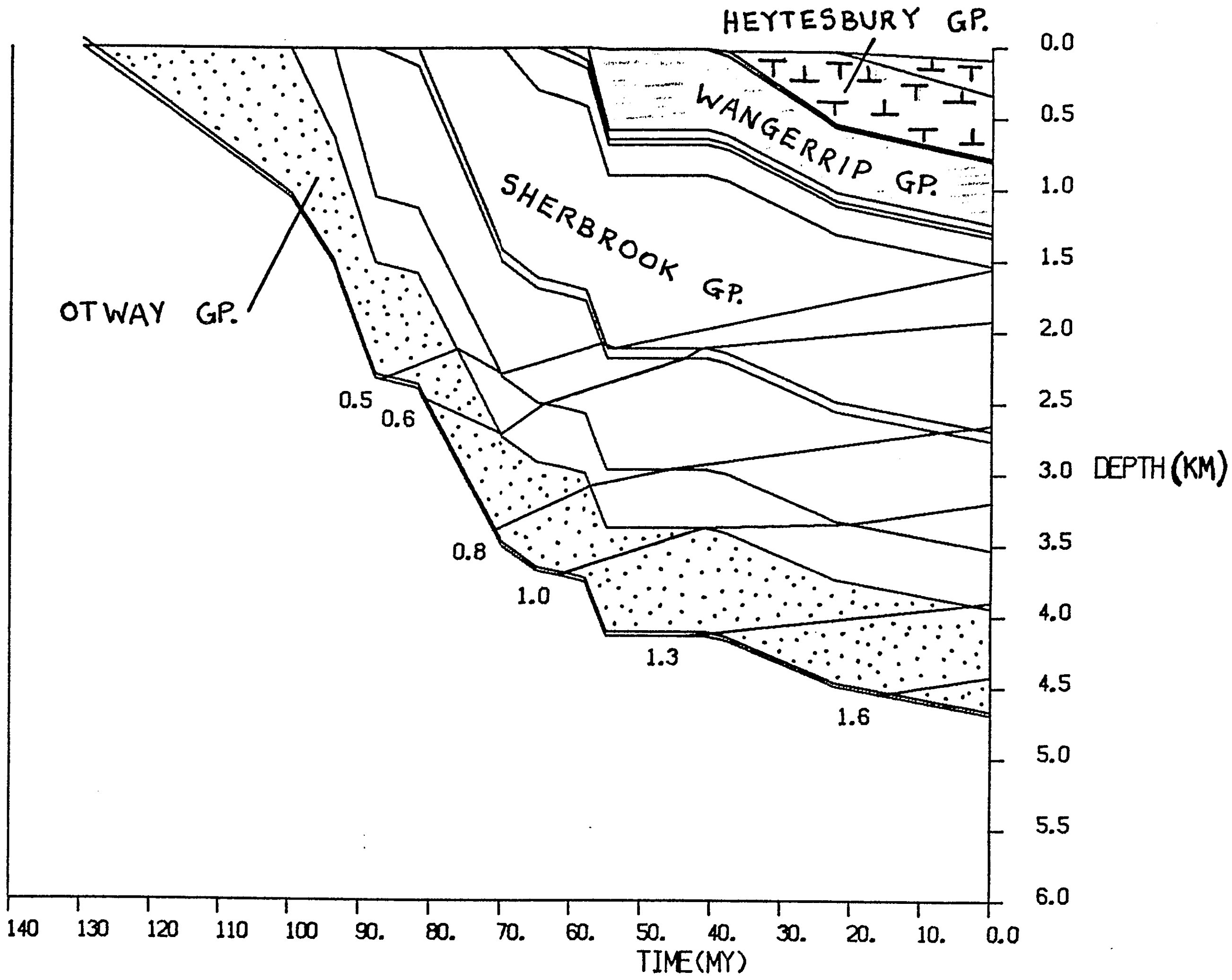

FIG. 3

Figure 4. Vitrinite reflectance model matched to the observed data from Table 1.