Appendix A:
A geochemical study of shale oils and bitumens derived from Kimmeridge Clay oil shales

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A.1 INTRODUCTION

Research was undertaken to determine the chemistry of the soluble organic fractions (bitumens) and shale oils (produced by pyrolysis at 500° C) of a selection of oil shales from the Kimmeridge Clay in order to make comment on the geological provenance of the oil shales, the possible commercial uses of the shale oils and to provide the basic data that would enable them to be compared with naturally occurring crude oils from southern England and the North Sea.

The overall nature and properties of the various compound classes within the oils (saturates, aromatics etc.) have been determined and detailed studies have been carried out to identify compounds of particular interest in the bitumens, in relation to their provenance (e.g. n-alkane distributions, pristane/phytane ratios), and in the shale oils in relation to their usefulness.

Artificial thermal diagenesis experiments have been carried out to determine what diagenetic changes are likely to have taken place in the bitumen and kerogen in the oil shale under natural conditions of deep burial in the U.K. continental shelf area.

The samples chosen for analysis were, as far as was practicable, representative of both the vertical (stratigraphical) and lateral (geographical) range of the oil shales. The potential oil yield of all the samples was determined by the modified Fischer Assay method.

A.2 SAMPLE PREPARATION AND ANALYTICAL METHODS

All solvents used were reagent grade, redistilled on an Oldershaw column. All glassware was cleaned by immersion in fresh chromic acid (25 g sodium dichromate dissolved in 50 cm^3 of distilled water, made up to 1 litre with concentrated sulphuric acid) for at least 3 hours, followed by washing with distilled water and oven drying. Soxhlet thimbles and cotton wool were pre-washed in clean solvent before use, and all column chromatography adsorbents were washed in solvent and re-activated in an oven before use.

On receipt of core samples, the outer 1 to 2 mm were removed by scraping with a clean scalpel to expose a fresh surface, and the core then placed in methanol in an ultrasonic bath for 10 to 15 minutes to remove any surficial organic contaminants. The air-dried washed core was then broken up inside clean aluminium foil with a clean hammer, to provide lumps 2 to 3 cm across: these were again washed rapidly in methanol before being air dried prior to crushing in a jaw crusher. Outcrop samples were scraped clean where possible, but difficult lumps were scrubbed with a clean wire brush prior to ultrasonic washing. Samples for Fischer Assay were removed from the jaw crusher and seived to pass BSS 2.36 mm aperture. The fraction held by BSS 850 μ m aperture was collected for Fischer Assay, whilst that passing through was further reduced in size by a disc mill (Tema) prior to geochemical analysis.

A.2.1 Potential Oil Yields

Potential oil yield of the shale was estimated by the modified Fischer Assay method (Stanfield and Frost, 1949) using a cast aluminium retort, but omitting the aluminium discs employed in the modified method above. Samples of Kimmeridge Clay oil shale that had been analysed by the same method at the Laramie Research Center of the U. S. Department of Energy, were used to calibrate the equipment. Due to the high specific gravity of the Kimmeridge shale oil, separation of oil and water could only be satisfactorily achieved by adding a known volume of strong brine solution prior to centrifugation. Oil specific gravity was determined by weighing a calibrated pipette containing the oil at a known temperature, the reading being corrected to 15° C.

Volatiles evolved from the shale under conditions similar to those employed for Fischer Assay, were determined on a Stanton MF-H1 termobalance under nitrogen. Samples of approximately 0.4 g, Fischer Assay size were heated from ambient to 500° C at 5.8° C per min., and held at 500° C until no further loss of volatiles was observed (Table A1).

A.2.2. Shale Oil Analyses

The asphaltene contents of shale oil samples was determined by pentane precipitation and weighing of the dried, filtered asphaltenes. Separation of the crude shale oil into chemical classes was achieved by column chromatography on columns of silica gel topped with one third alumina, with a column loading of 1:200. Elution with light petroleum spirit (B. P. 40-60° C) gave an aliphatic fraction; aromatics were then eluted from the column with dichloromethane, followed by elution with methanol to provide the heterocyclic fraction (the NSO fraction). Solvent from each fraction was removed by rotary evaporation on a cool (30° C) water bath to provide the respective fractions as oils. Since both aliphatic and aromatic fractions contained sulphur, it was necessary to remove this before the aliphatic and aromatic yields could be calculated. Sulphur was generally removed from the aliphatic fraction by the use of a short (10 cm) column packed with alumina topped with spongy copper. A solution of the aliphatic fraction in light petroleum spirit (B. P. 40-60° C) was usually desulphurised on elution from the column. Sulphur-containing compounds were also removed by silver ion thin layer chromatography (T. L. C.), a process which also separated the aliphatic fraction further into alkanes and alkenes. Elution of aliphatic fractions on plates coated with

Table A.1 Volatiles yield by Thermogravimetric Analysis

Sample No.	% loss at 100° C	loss of volatile % of whole rock 100° - 500° C
950	5.77	42.54
951	4.30	60.23
952	5.29	32.94
953	2.66	9.68
954	0.97	17.40
955	1.93	18.37
956	1.33	63.94
957	1.68	28.01
958	2.39	38.50
959	0.97	15.70
960	2.29	35.89
961	1.69	53.24
962	0.72	35.92
963	1.44	26.67
964	0.84	17.21
965	n.m	n.m
966	1.21	12.95
967	2.18	18.61
968	2.16	16.07
969	0.85	16.33
970	0.24	8.95
971	2.17	19.25
972	4.35	32.35
973	1.46	26.18
974	4.34	32.28
975	2.42	21.04

n. m. ... not measured

silica gel (Kieselgel HF_{254}) containing 3% silver nitrate, 0.5 mm thick gave two bands, Rf 0.8, Rf 0.5, in addition to a yellow non-mobile band, using 5% dichloromethane in light petroleum spirit (B. P. 40-60° C). Visualisation of the bands was achieved by running a standard alkane/ alkene mixture on a separated section of the plate alongside the sample, and spraying this section with rhodamine solution after development. The alkene band Rf 0.5, and the alkane band Rf 0.8 were scraped off the plate and the organic material recovered by washing with diethyl ether. The ether was removed on a rotary evaporater to give the required fraction as an oil (Fig. A. 1).

Sulphur-containing compounds were similarly removed from the aromatic fractions by silver ion TLC. Elution of 0.5 mm thick plates in dichloromethane gave two bands, Rf 0.55, pale blue fluorescence under ultra-violet light (280 nm), Rf 0.3, green-blue fluorescence, in addition to a dark brown band Rf 0.05, presumably sulphur-containing and high molecular weight compounds (e.g. porphyrins). The two colourless bands were scraped off, and the organics recovered to give pure aromatics.

Selected aromatic fractions were examined by high pressure liquid chromatography (HPLC) by Dr D. Grant at the British Carbonisation Research Association and the results compared with the chromatograms of known carcinogens.

A. 2. 3 Bitumen Analyses

Approximately 30 g samples of crushed (Tema) air-dried oil shale were extracted in a Soxhlet apparatus for 80 hours using a mixture of acetone 30%, chloroform 47%, methanol 23%. The organic solution was evaporated on a rotary evaporater in a cool (35° C) water bath to prevent undue loss of low molecular weight compounds. Acetone was added to the organic concentrate, and the mixture re-evaporated. The organic material was then transferred to a weighed glass vial, solvent removed with nitrogen, and the weight of extracted bitumen determined.

Analysis of the bitumen was conducted by chromatographic separation, on silica gel columns topped with 1/3 volume of alumina, and using a column loading ratio of 1:200. Elution with light petroleum spirit (B. P. 40-60° C) followed by dichloromethane, and finally methanol gave respectively aliphatic, aromatic, and NSO fractions. Alphatic fractions were further separated into alkenes and alkanes by silver ion TLC, using plates coated with silica gel (Kieselgel HF_{254}) containing 3% silver nitrate, 0.5 mm thick, and eluting with 5% dichloromethane in petrol. The required bands were scraped off and recovered with ether (Fig. A. 2).

Gas-chromatographic examination of fractions was achieved with a 25 m open tubular glass capillary column coated with OV-101 in a Carlo Erba 2150 gas chromatograph equipped with a flame ionisation detector. Temperature programming was employed from 40-250° C at

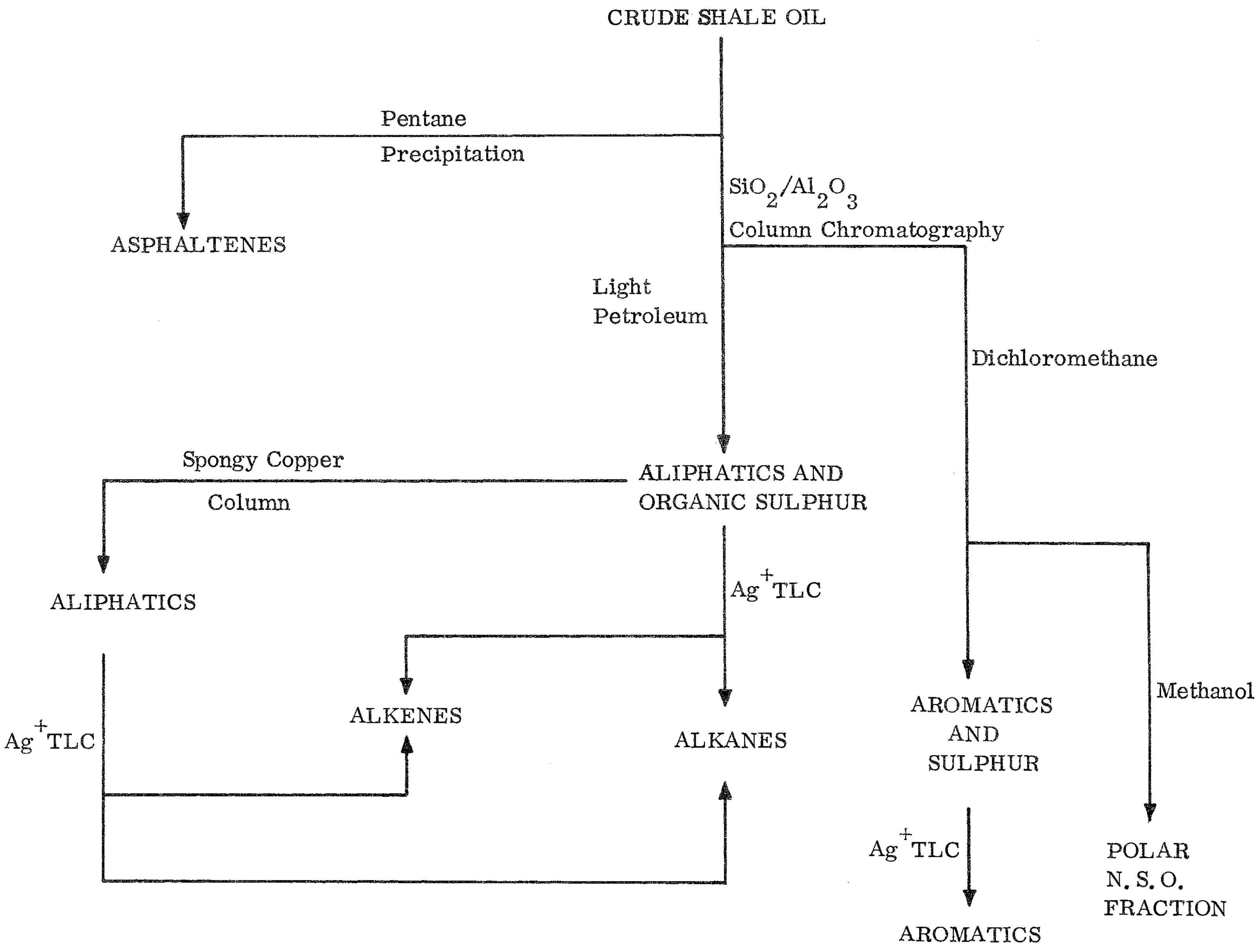

Figure A.1 Separation of crude shale oil

4° C per min., using hydrogen as carrier gas and operating with a detector/injector temperature of 300° C. To ensure reproducability in chromatographic data, an n-alkane standard was run before each series of chromatographic analyses, which also allowed the peak-height relationships of the sample to be accurately determined. Gas chromatographic peak identification was generally achieved by co-injection of an authentic standard with the unknown sample.

Combined gas-chromatography/mass spectrometry correlation data was obtained on a VG Micromass 12B mass spectrometer operating in multiple ion detection mode (MID) with a source temperature of 260° C, interfaced to a Varian 1200 gas chromatograph equipped with a 25 m open tubular glass capillary column coated with OV-101. Helium was used as the carrier gas, with an injector temperature of 290° C, and employing temperature programming throughout the run, the exact conditions depending on the ions being observed. For sterane/triterpane MID's temperature programming from 150° to 280° C was employed, at 2° C per min.

A. 2. 4 Diagenesis Experiments

Oil shale samples for artificial diagenesis experiments were crushed in the usual way (Tema) and de-bituminised by extraction for 80 hours using the same solvent system as in the bitumen extractions described above. Approximately 10 g samples of dried rock powder were weighed into thick walled glass Carius tubes which were then sealed under nitrogen before being placed in a furnace at the required temperature (usually 280° C) for the desired time. After reaction the tubes were cooled (-40° C), opened, and the rock powder extracted (Soxhlet) to remove the bitumen which was analysed in the above way by column chromatography followed by gas chromatography.

A.3 PROPERTIES OF THE SHALE OILS AND BITUMENS

A.3.1 Shale oil properties

Separation of the shale oil by the method described in **Fig.** A. 1 provided the values presented in Table 9 for the general composition of the crude shale oils. Due to the high sulphur content of both the aliphatic and aromatic fractions, removal of sulphur, detailed in the experimental method and effected by either spongy copper columns or silver ion TLC, was necessary before meaningful yields of hydrocarbons could be obtained. The weight of removed sulphur was summed for both aliphatic and aromatic fractions and presented in Table 9 as a sulphur percentage of the total oil, although this figure may represent a slight overestimation due to the removal of high molecular weight compounds with the organic sulphur. No attempt was made to separate sulphur compounds from the polar NSO fraction, although the odour of sulphur was not noticed in this fraction. An estimation of the sulphur content in each fraction has been attempted by comparing weights of fractions before and

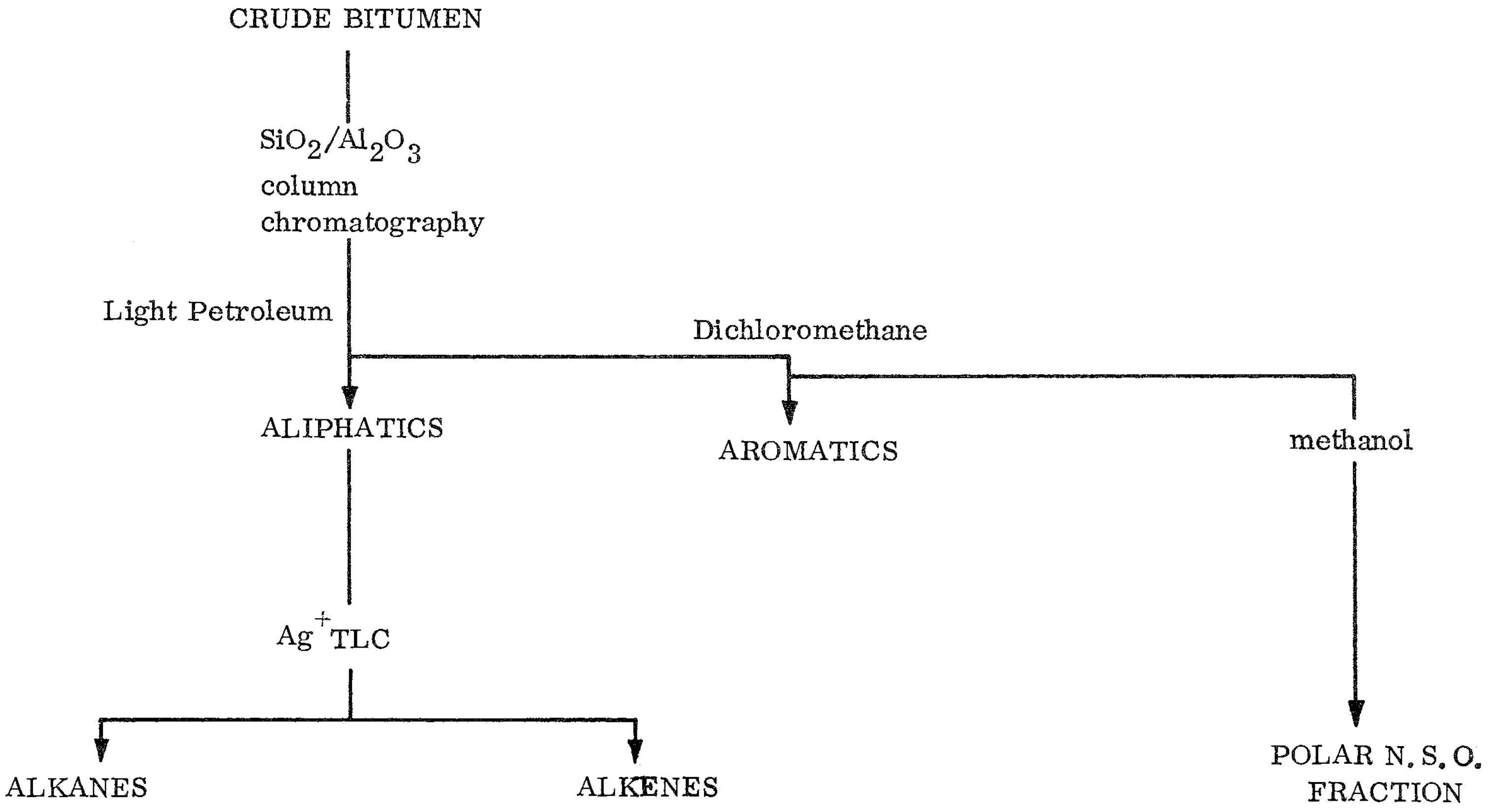

Figure A.2 Separation of crude bitumen

after sulphur removal, and the data is presented in Table 9. Organic sulphur is reported both as a weight per cent component of either the aliphatic or aromatic fraction and as a distribution of the total sulphur between the first and second fractions.

The aliphatic hydrocarbon fraction was further separated into alkenes and alkanes by silver ion TLC: yields of both are detailed in Table 10, presented as a weight percentage of the total crude shale oil.

Asphaltene levels for the shale oils range from 0.6 wt % to 7.3 wt % of the total oil and show no correlation with stratigraphy, locality or depth, although the four highest values are produced by high oil-yielding shales from Blackstone horizons. Hydrocarbons constitute between 15 and 30 wt % of the shale oil, there being no noticeable trends in the yields, and the polar NSO fraction generally amounts to a further 30 wt % of the oil: organic sulphur, calculated as above, constitutes on average a further 30 wt % of the total shale oil and is found in the first two hydrocarbon fractions. These contain considerable organic sulphur when originally prepared by column chromatography, the major quantity of sulphur (usually between 70 and 90 wt % of the total sulphur) residing in the aromatic hydrocarbon fraction: on average, about 30 wt % of the aliphatic hydrocarbon fraction is composed of organic sulphur, while sulphur can form over 80 wt % of the aromatic hydrocarbon fraction.

Of the hydrocarbons, aromatics predominate and vary over a considerable range from 5.8 to 28 wt % of the total oil, whilst the aliphatics vary from 1.1 to 13.2 wt %. There is no regional or stratigraphic correlation of the aliphatic/aromatic content of the oil. A detailed examination of the aliphatic hydrocarbon fraction shows it to contain a high proportion of unsaturates: often more than 50 wt % of the fraction is composed of unsaturates, but again the distributions show no noticeable trends. The high proportion of alkenes is probably the result of thermochemical reactions occurring during the pyrolysis conditions of the Fischer assay method. Generally shale oil is similar in composition to products derived by destructive distillation of high molecular weight fatty acids or ketones (Cane, 1976) and also bears a greater resemblance to coal-tar distillates (high proportions of aromatic and heterocyclic molecules) than to natural crude oils. Figure A.3 shows a typical capillary gas chromatogram of a separated unsaturates fraction, and shows a terminal n-alkene homology superimposed over an homology of possible alkadienes: also prominant are the unsaturated isoprenoids prist-1-ene and prist-2-ene, which will be discussed later.

Figure A.4 shows a capillary gas chromatogram of a saturated hydrocarbon fraction, and shows an n-alkane homology with an abundance of the isopreniod hydrocarbons phytane (iso-C_{20}), pristane (iso-C_{19}) and the C_{18} isoprenoid. The abundance of the C_{18} isoprenoid hydrocarbon is again the result of pyrolytic reactions. Table 10 shows an analysis of the alkane fraction of the oil, and tabulates pristane/phytane ratios, n-alkane CPI values between

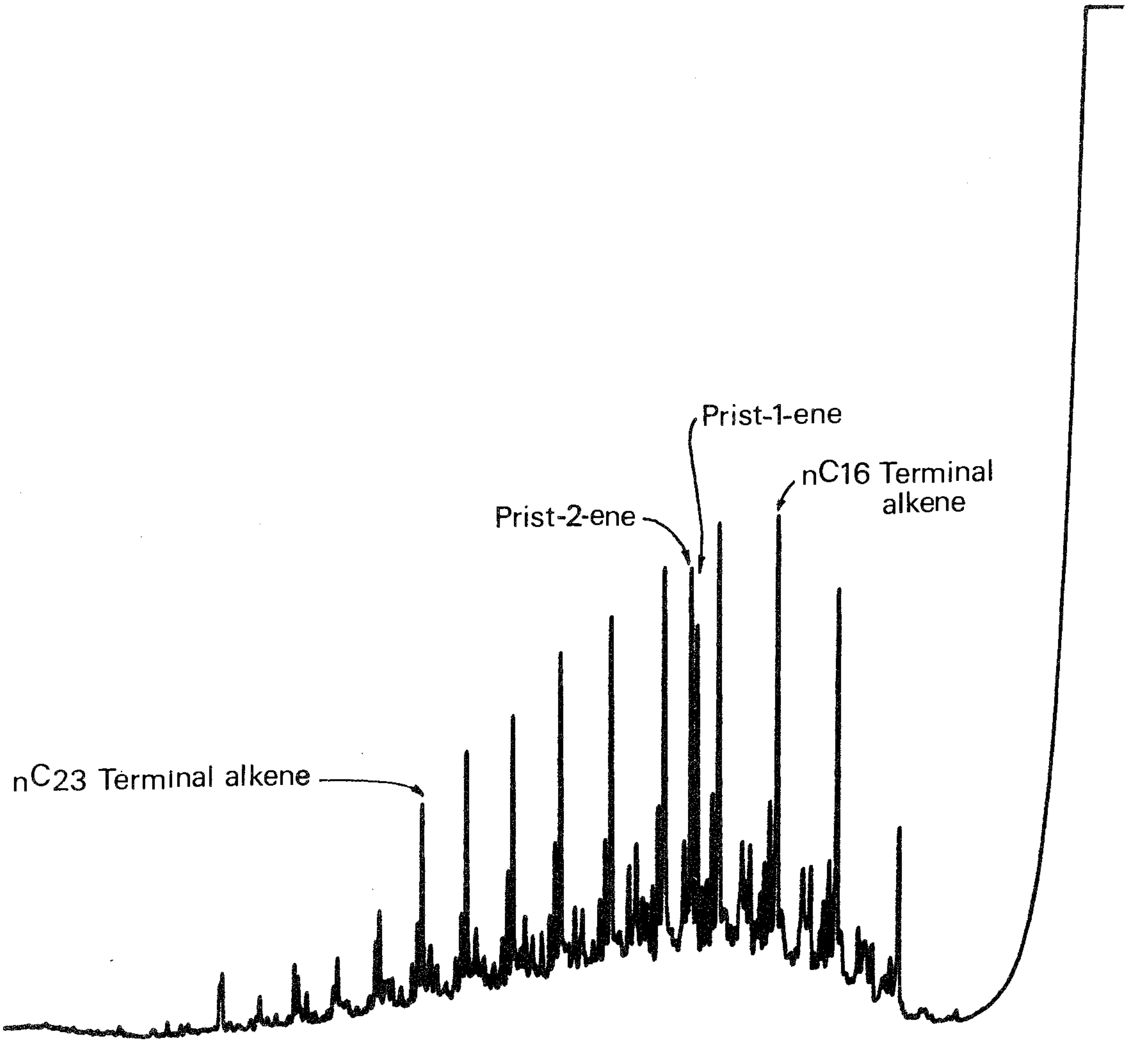

Figure A3 Gas chromatogram of the unsaturated aliphatic hydrocarbon fraction of a typical shale oil n-C_{20} and n-C_{30}, and the n-alkane distribution maximum.

Pristane/phytane ratios are seen to vary over a range from 0.53 to 1.44, and display higher values than the corresponding bitumen alkanes, whose values range from 0.35 to 1.08. It is suggested that the isoprenoid hydrocarbons pristane and phytane are derived from phytol, a degradation product of chlorophyll (Johns et al., 1966). In a study of the maturation and diagenesis of phytol Maxwell et al., (1971) has shown by stereochemical analysis that most, if not all pristane in sediments is produced from phytol. Simulated diagenesis experiments (Ikan et al., 1975; de Leeuw et al., 1977) verify this postulate, and Ikan further suggests that pristane is produced from phytol via reduction to dihydrophytol, followed by oxidation to phytanic acid and subsequent decarboxylation to give pristane. Generation of phytane is suggested by dehydration of dihydrophytol to phytene, followed by reduction to phytane. Boon and co-workers (1975) suggest an alternative route to pristane by oxidation of phytol to give phytenic acid, followed by decarboxylation to pristene and reduction to pristane.

The two opposed mechanistic pathways for the formation of pristane from dihydrophytol under oxidising conditions, and phytane from dihydrophytol under reducing conditions has led some authors to suggest that the pristane/phytane ratio is dependant on the redox potential of the depositional environment. A high pristane/phytane ratio would be expected in an oxidising environment and a low ratio would be expected under reducing conditions. Brooks and co-workers (1969) found that pristane was more likely in an oxidising, terrestrial environment while phytane was more prominent in reducing aqueous environments. Powell and McKirdy (1973) have used this ratio to distinquish between marine and non marine environments.

Pristane/phytane ratios in the shale oils have been affected by the pyrolysis conditions, and are all higher, indicating an increase in pristane relative to phytane. The increase in the ratio going from the bitumen to the corresponding shale oil is fairly consistent however, the oils having a pristane/phytane ratio on average 1.5 times the ratio found in the bitumens. This consistent increase would be expected if thermochemical reactions were the cause since during the generation of shale oil all the shales experience almost identical pyrolytic conditions. During thermal diagenesis dihydrophytol is converted to phytane, and phytanic acid to pristane (Lijmbach, 1975). Pristane could also be produced by the cracking of phytane, but Johns and Shimoyama (1972) suggest that decarboxylation reactions occur at lower energy, before the onset of cracking reactions. Brooks et al., (1969) has observed an increase in pristane production during coalification, up to a certain maturity level, and Burlingame and Simoneit (1969) suggest that pristane formation could occur by the cracking of C-C bonds of C_{20} isoprenoids linked to kerogen. To produce pristane by this mechanism a 1, 2 bond must rupture, but a more likely pathway is the breaking of the 2, 3 bond carrying

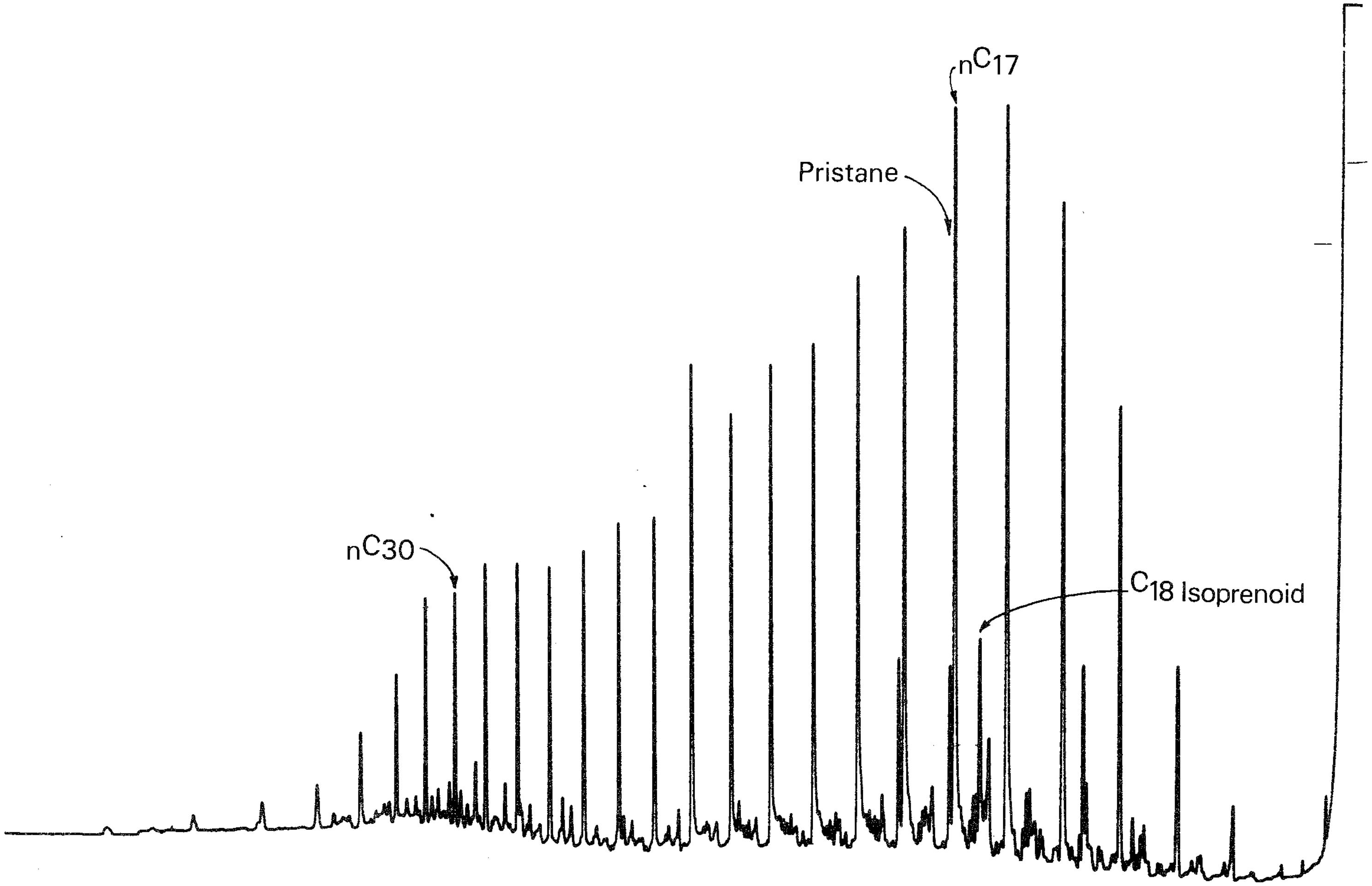

Figure A4 Gas chromatogram of the saturated hydrocarbon fraction of a typical shale oil the methyl substituent to give the C_{18} isoprenoid. Horsefield (1978) in a study of the Reindeer borehole observed an increase in pristane at the expense of phytane down the borehole, and an increase in C_{18} isoprenoids relative to both pristane and phytane below a certain level. He suggests that pristane production at high level is due to decarboxylation of phytanic acid, and the increase in C_{18} isoprenoids at lower levels due to the onset of cracking reactions.

It has been demonstrated that the Kimmeridge shale oils under investigation have large quantities of the C_{18} isoprenoid relative to the bitumens, and it is suggested that these are formed by pyrolysis, either from C_{20} isoprenoids bound to kerogen, or by cracking of C_{19} isoprenoids. (The cracking of the C_{20} isoprenoid is less likely since the loss of two carbon atoms are involved.) The C_{18} isoprenoid/pristane ratios are presented in Table A.2. for both pyrolysis oils and bitumens, and an increase can be observed going from the bitumen to the oil. This increase could either be due to an increase of the C_{18} isoprenoid, or a loss of pristane. Since the pristane/phytane ratio also shows an increase, this suggests an increase in pristane content, which has been observed and discussed earlier. Thus the increase in the C_{18}/pristane ratio represents an increase in the amount of C_{18} isoprenoid on pyrolysis of the shale kerogen. When the results from the artificial diagenesis experiments (see Section A) are also considered, an interesting sequence is observed. Going from the bitumen, the pristane/phytane and the C_{18}/pristane ratios increase after maturation at 280°C for 19 hours, and again show a further increase after 1 week at 280°C. The trend of the C_{18} isoprenoid continues in the pyrolysed shale oil while the pristane/phytane ratio drops, presumably due to phytane production or pristane cracking. This general trend is demonstrated in the three maturation experiments, all showing pristane/phytane ratios increasing to a maximum and then dropping to a value about 1.5 times that of the bitumens, and C_{18}/pristane ratios increasing continuously. The data is presented in Table A.3.

Thermodynamic effects also govern the production of the unsaturated isoprenoids observed in the alkene fraction. Pyrolysis of kerogens is reported to generate amongst other components, pristene (Maters et al., 1977) and Larter (1978) identified prist-1-ene and prist-2-ene in the products of kerogen pyrolysis, with prist-2-ene being the minor component. Pyrolysis of a phytol-containing melanoidin (artificial kerogen) again produced the two pristenes together with the C_{18} isoprenoid hydrocarbon. The greater proportion of prist-2-ene relative to prist-1-ene produced by shale pyrolysis under Fischer assay conditions is the result of the greater thermodynamic stability (S.R. Larter, personal communication) of the -2- isomer over that of the -1- isomer, the isomeric distribution representing the thermodynamic equillibrium which results from exposure of the oil to pyrolysis temperatures (500°C) for a time period greater than that employed by Larter in his pyrolysis experiments.

Table A.2 Analyses of shale oils: comparison of C_{18} isoprenoid/pristane ratios between shale oil and bitumen

n. m. ... not measured

Sample no.	C_{18} isoprenoid/pristane ratio shale oil alkanes	C_{18} isoprenoid/pristane ratio bitumen alkanes
950	1.19	0.10
951	1.60	0.16
952	1.40	0.15
953	1.50	0.08
954	0.70	0.21
955	0.75	0.26
956	1.14	0.14
957	0.97	0.16
958	1.30	0.23
959	1.43	0.19
960	0.88	0.14
961	1.00	0.13
962	0.95	0.14
963	0.92	0.21
964	1.06	0.13
965	1.44	0.12
966	0.88	0.13
967	1.60	0.32
968	1.43	0.11
969	1.23	0.12
970	0.97	0.10
971	1.20	0.11
972	1.28	0.15
973	0.80	0.21
974	n. m.	0.41
975	0.93	0.21

Table A.3 Comparisons of pristane/phytane and C_{18} isoprenoid/pristane ratios for alkanes from bitumens, artificial diagenesis experiments and shale oils

Sample no. and ratio	Bitumens	Artificial diagenesis		Shale oil
		19 hrs	168 hrs	
950 Pr/Ph	0.48	1.57	1.60	0.90
950 ISO C_{18}/Pr	0.10	0.66	0.55	1.19
953 Pr/Ph	0.35	1.66	2.20	0.53
953 ISO C_{18}/Pr	0.08	0.35	0.70	1.50
956 Pr/Ph	0.64	1.31	1.56	0.81
956 ISO C_{18}/Pr	0.14	0.28	0.60	1.14

Normal-alkane carbon preference indices (CIP) (Bray and Evans, 1961) are a measure of either the odd-, or even-carbon numbered alkanes predominating in an homologous series of n-alkanes, and have been used as indicators of maturity in sediments (Brooks and Smith, 1967; Tissot et al., 1971). In an immature sediment there is a high content of odd-carbon numbered n-alkanes presumed to have been formed by decorboxylation of even-carbon numbered acids, and hence the CPI is high. As the sediment matures the CPI falls as light n-alkanes are generated, and a smooth n-alkane envelope becomes apparent: recent sediments can have high CPIs, around 10, which fall to values around 2 to 5 for most immature sediments. Crude oils generally have CPI values close to unity. Decarboxylation reactions of saturated fatty acids are suggested (Cooper and Bray, 1963) to account for the increase in low molecular weight hydrocarbons with maturation. A more plausible argument is both odd and even n-alkane generation from kerogen diluting the original alkane distribution (Bray and Evans, 1965). The CPI values for the shale oils in the range from n-C_{20} to n-C_{30} are all around unity, varying from 0.70 to 1.17 and are all lower than the bitumen CPI values. CPI's below 1.0 indicate an even-carbon numbered n-alkane predominance, this phenomenon being observed in the products of the pyrolysis of Yallourn coal (Brooks and Smith, 1969), saponified coal macerals (Allan and Douglas, 1974), and lake sediments (Douglas et al., 1977), and for the shale oils reflects its pyrolytic origin.

The measured shale oil CPI values show no general trends except for shales from Blackstone horizons which show a decrease in value for the northern samples, dropping from 1.17 at Kimmeridge Bay to 0.84 at Marton. This is most probably the result of the variation in CPI of the shales themselves.

The n-alkane distribution maximum is also presented in Table 10. The n-alkanes show a unimodal distribution with maxima between n-C_{15} and n-C_{18}, and there is an approximate correlation between horizon and n-alkane maximum. Blackstone horizon shales generally yield alkanes with a maximum at the heavy C_{17} or C_{18} end, and result in oils with high specific gravities. Shales from the eudoxus zone generally produce alkanes with a maximum at the light, C_{15} end, and the oils have the lowest specific gravities. Shales from other horizons produce alkanes with intermediate n-alkane maxima around C_{16}, and produce oils with intermediate specific gravities. The general character of the alkane distributions can be observed in the capillary gas chromatograms appended at the end of this text: it is also apparent from the chromatograms that the proportion of steranes and triperpanes is much lower in the shale oils than in the bitumens.

Selected aromatic fraction gas chromatograms are given in Appendix H. All show a similar pattern of early alkyl-, and dialkylnaphthalenes with less well-resolved high molecular weight material at higher retentions. High pressure liquid chromatograms of four aromatic samples all show similar results and are also appended. Identification of polycyclic aromatic hydrocarbons is possible by high pressure liquid chromatography (HPLC), and the four aromatic fractions were screened by this technique for the presence of benzo(a)pyrene and fluoranthene, both potent carcinogens known to occur in coal tars, etc. (see Section 4 for discussion). None of the four samples provided spectra that could be assigned to either of the two carcinogens mentioned, and none of the peaks observed were in regions of the spectrum occupied by other known carcinogens. Separation and concentration of one aromatic fraction (KOS 956) followed by HPLC analysis also furnished no evidence for the presence of the two carcinogens.

A.3.2 Bitumen properties

Figure 33 shows the extractability of powdered whole rock samples of Kimmeridge oil shale by Soxhlet extraction. Soluble organic carbon values range from 0.36 wt % for a sample from the elegans zone (Tisbury Borehole) to 3.03 wt % for a sample from the Blackstone horizon (Kimmeridge Bay). A shale from the pectinatus Zone (Encombe Borehole) also exhibited a high extractability, soluble organic matter amounting to 1.8 wt % of the whole rock.

The Blackstone shales are generally found to be rich in soluble organic matter, with values ranging from 3.03 to 1.0 wt % in the southern localities, but becoming somewhat lower for northern samples. There is some correlation between extractability of the soluble organic matter and the potential oil yield of the shale. This correlation is shown in Fig. 33: as the potential oil yield increases so the extractability of the rock increases too, although not all high oil-yielding shales have high extractability. A shale sample from the Blackstone horizon at Foudry Bridge (KOS 950) has an oil yield of 50.3 US gallons/short ton but an extractability of only 0.93 wt %.

Chromatography of the crude bitumen as detailed in Fig. A.2 provides aliphatic, aromatic and NSO fractions, whose yields are reported in Table A.4. Fractions are presented as weight per cent of the total crude bitumen. A detailed examination shows the aliphatic +aromatic hydrocarbon fraction to constitute between 7.0 wt % (KOS 958) and 30.4 wt % (KOS 973) of the soluble organic matter, the polar NSO fraction ranging from 23.7 wt % at Encombe (KOS 962) to 55.2 wt % at Marton (KOS 953). No regional or stratigraphic trend is displayed in the distribution of the total hydrocarbons, the general proportion being between 8 and 20 wt % of the soluble organic matter. Shales from the Blackstone horizon at Marton and Kimmeridge Bay are exceptional in having bitumens containing about 30 wt % hydrocarbons. Aromatics again form the major part of the hydrocarbon fraction, and contribute between 10 and 16 wt %. Aliphatics contribute a much lower proportion of the hydrocarbon fraction, and vary from 1.1 to 8.9 wt %, with an exceptional value of 10.0 wt % recorded for a shale from the eudoxus zone at Kimmeridge Bay (KOS 955). Again no trend is displayed in the distribution of aliphatics and aromatics.

Separation of the aliphatic fractions by silver ion TLC provides alkenes and alkanes, whose yields are presented in Table A.4. Alkene/alkane ratios vary considerably, and in some samples the unsaturates predominate, although generally for the bitumens the alkene/ alkane ratio is lower, 1.15 compared to 1.27 for the shale oils. Alkene/alkane distributions show no defineable trend.

Figure A.5 shows a typical gas chromatogram of an alkane fraction in which the large proportion of material in the sterane/triterpane region is immediately apparent. Pristane and phytane also make significant contributions to the alkane fraction: pristane/phytane ratios are presented in Table A.5. They range from 0.35 to 1.63. If pristane/phytane ratios do reflect the depositional environment, as is widely suggested in the literature, then all the shales except the eudoxus Zone at Portesham (with a ratio of 1.63) have been deposited under reducing conditions. There is no observable trend in the pristane/phytane ratios, samples KOS 966, mentioned above, and sample KOS 973 being exceptional in their high values (1.63 and 1.08 respectively). The value at Marton (1.08) may indicate an increase in maturity of the sediment in this locality.

The alkane gas chromatogram shown in Fig. A.5 is characteristic of an immature sediment, with large peaks due to odd-carbon numbered n-alkanes predominating, and with prominant isoprenoid hydrocarbon peaks. The n-alkane CPI values in the range nC_{20} to nC_{30} are listed in Table A.5. They are noticeably higher than those of the shale oils,

Table A.4 Analyses of bitumens

n. m. ... not measured

Sample no.	Weight % of total oil			Weight % of bitumen	
	Aliphatics	Aromatics	Polar NSO fraction	Alkanes	Alkenes
950	1.9	10.9	28.2	0.9	1.1
951	1.7	9.7	27.7	0.2	1.3
952	1.6	7.2	26.2	0.8	0.6
953	2.3	6.5	34.7	1.0	1.0
954	6.6	14.4	26.6	n. m.	n. m.
955	10.0	19.8	30.3	n. m.	n. m.
956	2.4	18.2	26.2	n. m.	n. m.
957	1.9	13.8	30.7	n. m.	n. m.
958	1.3	5.7	29.9	0.8	0.4
959	2.6	4.9	27.0	0.9	0.8
960	2.4	13.8	38.4	1.1	2.4
961	3.7	17.7	27.3	1.1	1.6
962	5.3	17.7	23.7	2.4	2.4
963	2.8	13.7	44.7	2.0	1.7
964	4.5	12.2	42.2	0.4	0.9
965	1.5	11.9	35.3	0.2	1.5
966	2.5	8.1	34.4	0.9	1.4
967	1.2	6.4	42.1	0.8	0.6
968	1.1	9.2	36.3	0.9	1.2
969	1.9	10.1	40.9	1.1	1.3
970	4.1	15.1	55.2	0.7	1.7
971	2.1	7.7	38.2	1.4	0.5
972	2.5	8.3	32.9	0.9	0.9
973	8.9	21.5	38.0	2.2	0.6
974	3.0	10.5	41.0	0.8	1.3
975	4.1	13.2	37.5	1.9	1.9

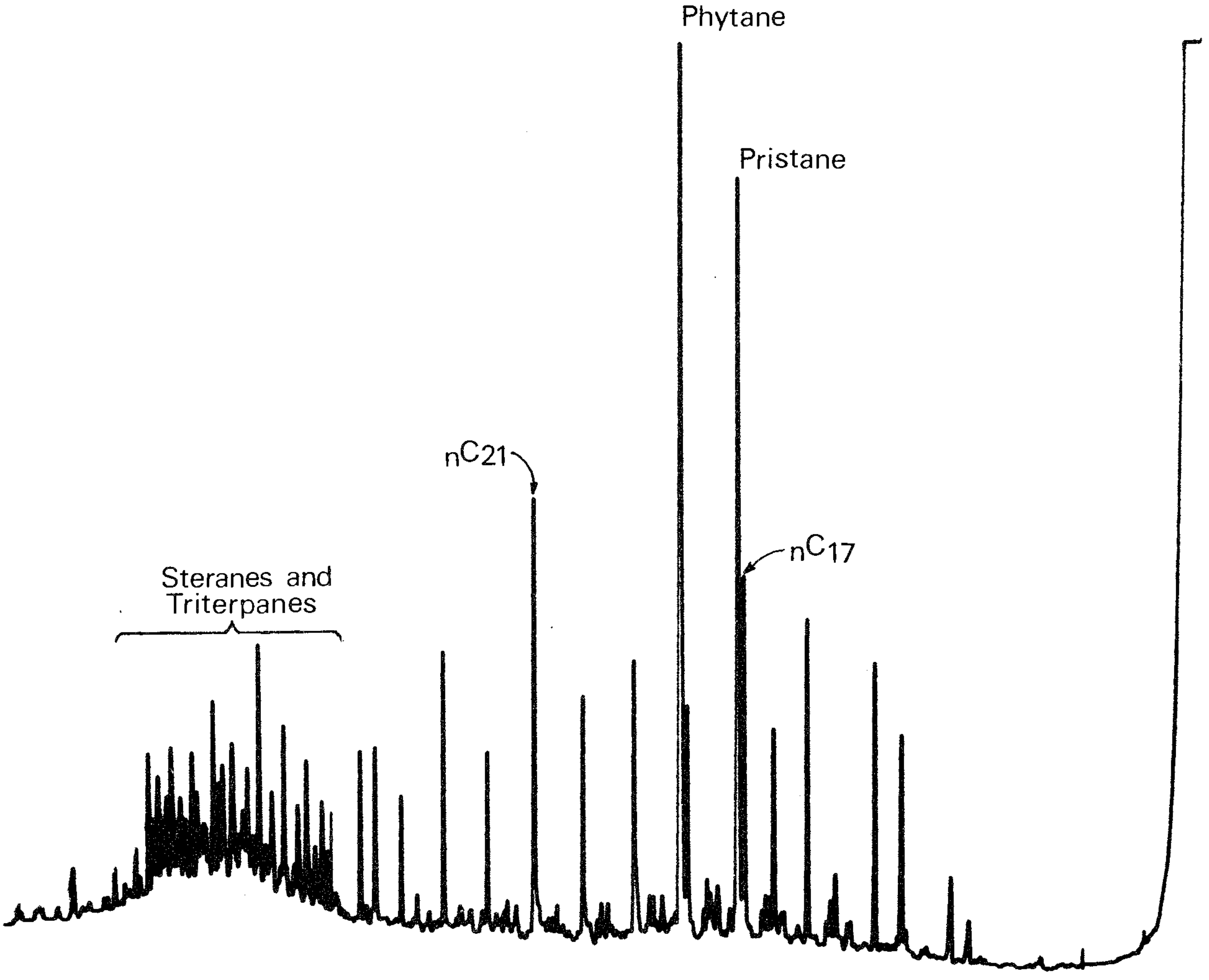

Figure A5 Gas chromatogram of the alkane fraction of a typical bitumen

Table A.5 Analyses of bitumens

Sample no. (KOS)	Pristane/Phytane ratio	Normal Alkanes	
		CPI nC_{20}-nC_{30}	Maxima
950	0.48	2.35	C_{17}, C_{23}
951	0.53	2.84	C_{17}, C_{23}
952	0.57	2.06	C_{17}, C_{23}
953	0.35	2.51	C_{17} (C_{21}, C_{23})
954	0.79	1.81	C_{17} (C_{21}, C_{23})
955	0.76	1.61	C_{17}, C_{23}
956	0.64	3.16	C_{17}, C_{23}
957	0.62	1.48	C_{17} (C_{21}, C_{23})
958	0.82	2.58	C_{17}, C_{21}
959	0.77	1.46	C_{15}, C_{23}
960	0.89	2.34	C_{17}, C_{23}
961	0.92	2.37	C_{17} (C_{21}, C_{23})
962	0.89	2.38	C_{18} (C_{21}, C_{23})
963	0.55	1.42	C_{17}, C_{23}
964	0.63	1.79	C_{17}, C_{23}
965	0.69	2.10	C_{17}, C_{23}
966	1.63	2.00	C_{17}, C_{23}
967	0.63	1.80	C_{17} (C_{21}, C_{23})
968	0.61	2.19	C_{17}, C_{21}
969	0.62	1.90	C_{17}, C_{23}
970	0.52	1.16	C_{19}
971	0.52	1.45	C_{17}, C_{21}
972	0.51	1.86	C_{17}, C_{23}
973	1.08	1.35	C_{17} (C_{23})
974	0.65	1.76	C_{17}, C_{21}
975	0.75	1.64	C_{17}, C_{21}

ranging from 1.16 for a eudoxus Zone bitumen at Reighton (KOS 970) to 3.16 for a Blackstone bitumen from Kimmeridge Bay. The CPI values present little stratigraphic correlation except for shales from the Blackstone horizon, whose CPI values are generally higher than the rest, and range from 3.16 at Kimmeridge Bay, to 2.06 at Tisbury. The northern samples northward of North Runcton show much lower CPIs, however, ranging from 1.76 at North Runcton through a low value of 1.35 at Marton, to 1.86 at Donington on Bain. Differentiation of other stratigraphic levels is not possible by CPI values, but both the elegans and eudoxus zones show the same trend of decreasing towards the north. Elegans Zone samples at Kimmeridge Bay and Tisbury have CPI values of 1.81 and 2.19, while similar horizons at Donington on Bain and Reighton show values of 1.45 and 1.64. Eudoxus Zone samples vary from 2.5 to 1.6 in the southern part of the area, dropping to 1.8 at Hartwell and 1.16 at Reighton, the lowest CPI value observed. To the south of the London Platform the eudoxus Zone at Warlingham has a CPI value of 1.46.

In some boreholes the CPI values decrease with increasing depth down the borehole. This general trend has been observed by many workers, for example Bray and Evans (1961) and Brooks and Smith (1967) and it is regarded to be the result of dilution with light n-alkane generated with increasing depth. The Portesham, Warlingham, Foudry Bridge, Donington on Bain and Reighton boreholes all show this trend. Samples from Kimmeridge Bay also show this decrease in CPI, while at Tisbury results are inconclusive: The Encombe Borehole shows the reverse trend, the values increasing down the borehole to the Blackstone horizon.

The decrease of CPI value northwards is a further indication of the increasing maturity of the sediments in this direction. The gas chromatogram of the n-alkanes for the bitumens from the Marton Borehole shows a relatively smooth envelope indicative of a greater maturity than any of the samples from southern localities. An increase in maturity is also indicated in the eudoxus Zone in the Warlingham Borehole (KOS 965) with a CPI value of 1.46 compared to the Blackstone horizon in the same borehole, with a CPI value of 2.58. A similar maturity increase is also noticed in the Reighton borehole, the elegans Zone having a CPI of 1.64 whilst the eudoxus zone produces a value of 1.16.

The distribution of n-alkanes in the bitumens is generally bimodal with maxima at n-C_{17} and n-C_{23}, with n-C_{21} also dominant in some samples. The maximum at n-C_{17} can be ascribed to an algal source. Gelpi and co-workers (1970) found an n-C_{17} maximum in the hydrocarbons from estuarine and marine environments containing blue-green algae, and Gibbons (1978) found n-C_{17} to be the domenant alkane in algal-mat sediments of the Middle East. This hydrocarbon could arise by decarboxylation of the n-C_{18} fatty acid, and the dominance of n-C_{16} and n-C_{18} fatty acids found in algal lipids by Cardoso et al. (1976) would account for the dominance of the n-C_{17} alkane. Algae have also been shown to secrete hydrocarbons, and Gelpi et al. (op cit.) have identified the n-C_{17} alkane as the major hydrocarbon secreted by green algae; this could also account for the observed alkane dominance in the Kimmeridge Clay oil shales. Whatever mode is operative there can be little doubt that it is algal in origin.

The maximum at n-C_{23} is more difficult to explain. A range of alkanes between n-C_{16} and n-C_{24} has been ascribed to a marine input (Powell and McKirdy, 1973), that from n-C_{25} to n-C_{30} representing the main contribution from land plants. Thus the n-C_{23} maximum falls close to the borderline between marine and terrestrial inputs, but the lack of land-derived material observed in Kimmeridge shales under the microscope tends to disfavour a major contribution from terrestrial sources. The n-C_{23} alkane is not widely reported, but it has been found in pine needles (Han, Calvin et al., 1968). Bray and Evans (1961) report a range of n-alkanes from n-C_{23} to n-C_{35} from diverse environments, while Coates (1977) has found n-C_{23} to be the major n-alkane in the hydrocarbon extract of a Scottish peat. A peaty source would seem more satisfactory in explaining the observed n-C_{23} maximum in the n-alkane distributions in the Kimmeridge shale bitumens. Gitmez and Sargeant (1972) have suggested that the Kimmeridge oil shales were deposited adjacent to shallow swampy areas which supplied the necessary colloidal humics to form the kerogen: they also state that marine algae are not important as organic progenitors. Peat-derived n-C_{23} alkanes would corroborate the swamp environment, but the predominance of the n-C_{17} alkane must indicate a large contribution from algae, probably existing in the lowest levels of the coastal swamps, and stretching out into the shallow seas.

Pentacyclic triterpanes of the hopane type have been identified in crude oils and sedimentary organic matter (Ensminger et al., 1973) and are generally found in considerable quantities. These biological marker molecules have been used as a means of fingerprinting crude oils (for example Pym et al., 1975), and have been used for source rock/crude oil correlations (Seifert, 1977; Seifert, 1978).

Kimmeridge Clay oil shale bitumens contain considerable quantities of bio-marker molecules and an attempt has been made to use various measured triterpane isomer ratios for correlation and comparison purposes. Table A.6 shows measured values for selected samples of both bitumen and shale oil aliphatics obtained by combined gas chromatrography-mass spectrometry in the multiple ion detection mode monitoring ions at m/e 191 (triterpanes) and m/e 217, (steranes). Table A.6 presents two sets of parameters, the ratio of the C_{27} 17 α H trisnorhopane to the C_{27} 17 β H trisnorhopane, and the ratio of the C_{30} 17α H hopane to the C_{30} 17 β H moretane. The three bitumens studied all show similar values for 17α H/17 β H ratios for the C_{27} trisnorhopanes, no stratigraphic correlation being displayed in the Blackstone samples KOS 950 and 956,

Table A.6 Triterpane Correlation Ratios
For B: Bitumens
O: Shale Oils

Sample	$\frac{C_{21}\ 17\alpha\ \text{H Trisnorhopane}}{C_{21}\ 17\beta\ \text{H Trisnorhopane}}$	$\frac{C_{30}\ 17\alpha\ \text{H Hopane}}{C_{30}\ 17\beta\ \text{H Moretane}}$
950 B	0.83	0.44
955 B	1.01	5.00
956 B	1.01	4.00
956 O	3.80	1.10
963 O	3.03	0.90
968 O	1.40	0.80

whose ratios are similar to the eudoxus Zone sample KOS 955. Again no stratigraphic correlation is displayed when the 17 α H/17 β H ratios for the C_{30} hopane/moretane are examined. The two Blackstone horizon samples have ratios of 0.44 and 4.0, while the eudoxus Zone sample has a ratio of 5.0, indicating a possible correlation with locality, both samples from Kimmeridge Bay (KOS 955 and 956) having relatively large proportions of the C_{30} 17 α H hopane (and high 17 α H/17 β H ratios) compared to the much lower proportion of C_{30} 17 α H hopane in the Blackstone sample from Foudry Bridge (KOS 950).

By contrast, shale oils derived from the same horizons contain much higher proportions of C_{27} 17 α H compared to C_{27} 17 β H trisnorhopane, giving high ratios. The increase in the C_{27} 17 α H at the expense of the C_{27} 17 β H trisnorhopane is a result of the former's greater thermodynamic stability (Ensminger et al., 1973) and is the reason that all the shale oils present higher C_{27} 17 α H/17 β H ratios than the bitumens. The C_{30} 17 α H hopane to C_{30} 17 β H moretane ratios in the oils are generally lower than the bitumens studied indicating an increase of the C_{30} moretane relative to the C_{30} hopane. This increase of C_{30} 17 β H moretane on pyrolysis has also been observed by Seifert (1978). Natural maturation processes convert C_{30} 17 β H 21 β H to the more stable C_{30} 17 α H 21 β H hopane, but the large amount of energy available under pyrolysis conditions is sufficient to cause an isomerisation at C_{21} from the 21 β to the 21 α configuration, thus producing the C_{30} moretane (17 β H 21 α H) under these conditions.

Table A.7 Artificial diagenesis experiments: bitumen analysis

Conditions A: 19 hrs at 280° C
B: 168 hrs at 280° C

Sample No.	Isoprenoid ratios		n-Alkanes	
	Pr/Ph	ISO C_{18}/Pr	CPI $nC_{20}-nC_{30}$	Maximum
950 A	1.57	0.66	1.18	C_{21}
950 B	1.60	0.55	1.12	C_{19}, C_{21}
953 A	1.66	0.37	1.42	C_{20}, C_{23}
953 B	2.20	0.70	1.04	C_{17}, C_{20}, C_{23}
956 A	1.31	0.28	1.08	C_{20}
956 B	1.56	0.60	0.95	C_{20}

discussed earlier in the text. Further evidence of thermal generation is given by the production of the C_{18} isoprenoid hydrocarbon, and the C_{18} isoprenoid to pristane ratio generally increases with prolonged heating (cf. Table A.7).

The n-alkane CPI values in the range nC_{20} to nC_{30} are all much lower than that of the corresponding bitumens, indicating an increase in maturity, and for one sample, 956 (168 hours heating), the CPI value is 0.95. This change in CPI from unmatured to artificially matured bitumen is shown in Table A.7. Again it is observed that prolonged heating decreases the CPI value of the n-alkanes. The n-alkane distributions also show a great increase in maturity compared to the original bitumens, and bear a greater resemblance to the North Sea crude oils. The normal alkane distributions are generally unimodal with maxima in the nC_{20} region, heavier than that of the natural North Sea crudes. Figure shows a comparison of alkanes from an unmatured Kimmeridge bitumen, an artificially matured Kimmeridge sample, and a North Sea crude: the similarity of the latter pair compared to the first is immediately apparent. Gas chromatograms of the artificially matured bitumen alkanes are presented in Appendix H, together with a sequence of alkane chromatograms from the unmatured to the 168 hour matured shales.

From the limited examination of the triperpane correlation parameters, the C_{27} $17\alpha H/C_{27}$ $17\beta H$ trisnorhopane ratio is found to be 4.0: this is much higher than that for the corresponding bitumen (as expected) and is slightly higher than that of the equivalent shale oil.

Thus, by these simulated diagenesis experiments, the maturity of the Kimmeridge

Table A.8 North Sea crude oil analysis: general composition

Sample No.	Weight % of Total Oil		
	Aliphatics	Aromatics	NSO Fraction
KOS 1801	44.1	13.9	18.8
KOS 1802	41.1	35.3	16.4
KOS 1803	50.2	29.2	13.6
KOS 1804	30.4	33.9	20.8

A.4 OIL-SOURCE ROCK CORRELATIONS

Samples from seven oil seepages in Dorset and Sussex (see p. 131 for details) were examined by extraction and column chromatography, but on closer examination of the aliphatic fractions by gas chromatography, only unresolved "humps", characteristic of biodegraded oils were found. The samples were therefore useless for correlation purposes.

Samples of four North Sea crudes were also examined for comparison purposes. They were subjected to column chromatography with the results shown in Table A. 8. All the oils are rich in aliphatics, and in one sample (KOS 1803) aliphatics amount to over 50% of the total crude (Table A. 8). Aromatics are found to be subordinate to the aliphatics and range from 8.4 wt% to 35.3 wt% of the crude, with the NSO fraction making up a further 20.8 wt% (maximum). On examination of the alkanes (Table A.9) pristane/phytane ratios are seen to vary from 0.96 to 1.61. The n-alkanes show a slight even-carbon number preference in the nC_{20} to nC_{30} region, with CPI values just below 1.0. The n-alkane envelope shows a typically mature, smooth unimodal distribution maximising at the lighter end between nC_{13} and nC_{15}. Alkane gas chromatograms of the North sea crudes are shown in Appendix H. As would be expected, all the crudes show alkane parameters very unlike

Table A.9 Analyses of alkane fractions of selected North Sea oils

Sample No.	Pristane/Phytane ratio	Normal Alkanes	
		CPI nC_{20}-nC_{30}	Maximum
KOS 1801	1.25	0.93	C_{13}
KOS 1802	1.61	0.99	C_{13}
KOS 1803	1.00	0.98	C_{13}
KOS 1804	0.96	0.97	C_{15}

Table A.10 Artificial diagenesis experiments: bitumen analysis

Conditions A: 19 hrs at 280° C

B: 168 hrs at 280° C

Sample No.	Soluble Organic Matter, Weight % of Whole Rock	Weight Percent of Crude Bitumen		
		Aliphatics	Aromatics	NSO
950 A	6.04	3.0	30.4	39.6
950 B	5.38	4.0	33.4	21.4
953 A	1.44	2.8	12.2	46.8
953 B	1.38	4.6	16.4	29.6
956 A	18.04	3.0	23.8	40.0
956 B	13.26	3.6	31.0	29.4

those of the bitumens from the Kimmeridge Clay of the land area.

The character of the Kimmeridge Clay bitumens can be modified to show greater similarity to the crude oils by artificial diagenesis. In a series of simulated diagenesis experiments debituminised, powdered Kimmeridge Clay oil shale was heated at 280°C, in sealed tubes for either 19 hours or 168 hours and the contents subsequently extracted and subjected to column chromatography. Extraction and chromatography data are presented in Table A.10.

It is immediately apparent that the diagenesis experiments dramatically increase the soluble organic matter content of the shale, by a factor of approximately 6 for samples KOS 950 and 956, and by about 4 times for KOS 953. It is also interesting to note that the extended heating time of 168 hours reduces the quantity of soluble organics. For either of the two heating times, the yields of aliphatics, aromatics and NSO fractions are all higher than those of the original bitumens. Aromatics again predominate, and range from 12.2 wt % to 33.4 wt % of the total soluble organic matter, while the aliphatics vary from 2.8 to 4.0 wt % of the total. Longer heating times produce greater quantities of aliphatics and aromatics, but the yield of the NSO fraction decreases: for sample KOS 950 it is reduced by a factor of 2, while for KOS 953 and 956 the reduction in yield is less dramatic.

On closer examination of the alkane fraction (Table A.3) pristane/phytane ratios for all the artifically matured samples are all above 1.0 ranging from 1.30 to 2.20, and are all much higher than the corresponding bitumens. The pristane/phytane ratios are seen to increase with extended heating times, most probably the result of the thermal generation of pristane by the cracking of phytane or a C_{20} isoprenoid bound to kerogen,

Table A. 11 Artificial diagenesis experiments: change in n-alkane CPI from unmatured to artificially matured bitumen

Sample No.	n Alkane CPI, nC_{20}		
	Unmatured	19 hours Maturation	168 hours maturation
950	2.35	1.18	1.12
953	2.51	1.42	1.04
956	3.16	1.08	0.95

shale bitumen can be increased from a very immature one showing high odd-carbon number preference and a bimodal n-alkane distribution maximising at nC_{17} and nC_{23}, to a bitumen having a high degree of similarity with natural North Sea crudes, displaying low CPI values and smooth, unimodal n-alkane distributions maximising generally in the nC_{20} region (Table A.11).

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Appendix D:
Isotopic analyses of carbon and sulphur in oil shales from the Kimmeridge Clay

Part 1: Carbon isotopes
Part 2: Sulphur isotopes

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Appendix D:
Isotopic analyses of carbon and sulphur in oil shales from the Kimmeridge Clay

Part 1: Carbon isotopes

INTRODUCTION

Carbon isotope ratios in organic matter in sediments give a wide range of values. The proportion of terrestial organic material in a marine sediment will affect the ratio (Sackett and Thompson, 1963). The different constituent compounds each has a specific range of isotopic values (Degens et al., 1968) and thus maturation will also affect the ratio as certain constituents are selectively degraded.

Carbon has two stable isotopes: the minor, ^{13}C, occurs to an extent of about 1.1% with respect to the major, ^{12}C. Since the variations in relative abundance are small when expressed in percentage terms it is usual to employ the del notation. The $^{13}C/^{12}C$ ratio of a sample (R^{13}) is given as parts per thousand (per mil or ‰) deviation from that ratio in an international standard. All values are quoted relative to carbon in PDB, the international calcite standard (Craig, 1957).

$$\delta^{13}C \text{ (in ‰)} = \left(\frac{R^{13}\text{sample} - R^{13}_{\text{PDB}}}{R^{13}_{\text{PDB}}}\right) \times 1000$$

Consequently, a negative del value means that the sample is depleted in ^{13}C relative to PDB, which is the case for most sedimentary organic materials. Samples that are enriched or depleted in ^{13}C are referred to respectively as isotopically heavy or light.

In general, marine plants are approximately 10‰ heavier than terrestial ones but both show a fairly wide range of values (Craig, 1953). Most animal tissues reflect the isotopic composition of their food with little fractionation and thus display a wide range of values. Despite this, organic carbon in Tertiary or Recent pelagic sediments show a surprisingly small extent of variation; from about -19‰ to about -23‰ (Eckelmann et al., 1962). A systematic change from -21‰ to -26‰ in sediments successively closer to the Gulf Coast shore was noted by Sackett and Thompson (1963) and attributed to an increasing contribution from terrestial plants.

In pre-Tertiary sediments the carbon shows lighter values clustering around -28‰ but the range extends from -22‰ to less than -35‰ (the latter value from Pre-Cambrian sediments). However, organic matter in the Upper Lias (Jet Rock) also consists of very light carbon, from -29‰ to -36‰ (Coleman and Raiswell, 1978). There are two possible explanations for the lighter carbon in older sediments both of which relate to maturation:

the relatively heavy components are more readily degraded (e.g. carbohydrates) leaving the residue light; terrestial material, which is lighter, may be retained preferentially during diagenesis possibly due to the larger size of fragments.

For the present study kerogen was extracted from samples of Kimmeridge Clay and analysed for $\delta^{13}C$ values. It was hoped that the data would define the range of $\delta^{13}C$ values and enable comment to be made on the applicability of the carbon isotope method to oil-source rock correlations in the Kimmeridge Clay.

ANALYTICAL TECHNIQUES

Each sample of oil shale was ground to -120, +240 mesh and a portion of about 3 to 5g was taken for extraction of kerogen using a method based on that of Saxby (1976). The different stages of the procedure successively dissolve unwanted constituents, leaving the residue for further treatments. The powder, in a P.T.F.E. beaker, was moistened with water before the addition of 10 ml of 3N hydrochloric acid to dissolve carbonates and some sulphates. After the effervescence had subsided the process was completed by heating on a hot-plate at about 45°C for 40 minutes. 30 ml of a 2:1 mixture of concentrated hydrofluoric acid and 3N hydrochloric acid was added to dissolve silicates and silica. The sample and acids were heated for one hour at about 55°C. Finally, the residue was warmed carefully with 10 ml of 2N nitric acid at the same temperature for 45 minutes to remove pyrite prior to washing with water and freeze-drying.

It is possible that some quartz and pyrite remained after the treatment and that some oxidation or nitration of the kerogen may have occurred. However, it is thought unlikely that this will have affected the measured carbon isotope composition.

For isotopic analysis carbon must be in the form of carbon dioxide. The oxidation of the kerogen must be as complete as possible to avoid fractionation effects and the carbon dioxide must be separated from other gases. A small sample of kerogen weighing about 3 mg was ground with 200 mg cuprous oxide and heated in vacuo at 1070° C. The details of the apparatus and procedure are the same as those used for the preparation of sulphur dioxide for isotopic analysis (Coleman and Moore, 1978).

RESULTS

The carbon dioxide was analysed on a Micromass 602-C isotope ratio mass-spectrometer and the data were corrected for isobaric interference and instrumental effects in the normal way (Craig, 1957; Deines, 1970). The preparation of the gas sample introduces a small contribution of blank carbon dioxide from the cuprous oxide and the silica glass furnace tube. Fortunately, both the volume and isotopic composition of the blank are constant and a small correction can be made to the final answer. The results are summarised in the table below.

Sample (KOS)	Corrected $\delta^{13}C$
1305	-19.3
1306	-26.1
1307	-23.0
1309	-27.7
1312	-30.6
1316	-24.1

It can be seen that the data cover a wide range that encompasses that of sediments ranging from Recent to pre-Tertiary in age.

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Part 2: Sulphur isotopes

INTRODUCTION

Sulphur has four naturally occurring isotopes, ^{32}S, ^{33}S, ^{34}S and ^{36}S, the relative abundances of which vary as a function of physical or chemical processes. However, it is usual to measure only the change in ratio of the two most abundant isotopes, $^{34}S/^{32}S$ (a value of about 1 to 22). Since the determination of absolute isotopic abundances is difficult and because the variations are usually very small they are measured as parts per thousand (‰) deviation from the $^{34}S/^{32}S$ ratio in an international standard, troilite from the Canon Diablo meteorite (CD). These units of deviation are called δ units, and expressed thus:

$$\delta^{34}S,\ ‰ = \left(\frac{^{34}S/^{32}S\ \text{sample} - {}^{34}S/^{32}S_{CD}}{^{34}S/^{32}S_{CD}}\right) \times 1000$$

Samples that are enriched or depleted in the heavier isotope relative to the standard will have a positive or negative $\delta^{34}S$, respectively and are referred to as isotopically heavy (+ve) or light (-ve). All references to isotopic composition in the following report refer to $\delta^{34}S$.

The sulphur isotopic composition of sea-water and recent evaporites is uniform at about +21‰ (Rees et al., 1978). However, analyses of geologically older evaporites by Thode and Monster (1965) have shown that the isotopic composition of sea-water sulphate has varied considerably in the past but that the sea-water values were uniform at any one time. A recent compilation of variation in data for sea-water with time (Fig. D1) has been given by Holser (1977).

The bacterial reduction of sea-water sulphate to sulphide under anaerobic conditions in sediments can cause fractionation of the sulphur isotopes to give a mixture that can be more than 45‰ lighter than the original sulphate (Nakai and Jensen, 1964). The degree of the fractionation is controlled by many factors, including the nature of the organic substrate and the availability of sulphate (Rees, 1973). Similarly, sedimentary sulphide ores were assigned a bacteriogenic origin and shown to be on average 18‰ lighter than the sea-water from which they were derived (Sangster, 1968). More recently a review by Schwarcz and Burnie (1973) reported data in which two types of isotope value distribution were related to bacterial reduction in either a closed system or in deep euxinic basins with free access of sulphate. Despite this, Thode and Monster (1965) showed that the sulphur isotope composition of oils of widely different ages from worldwide sources were in general 15‰

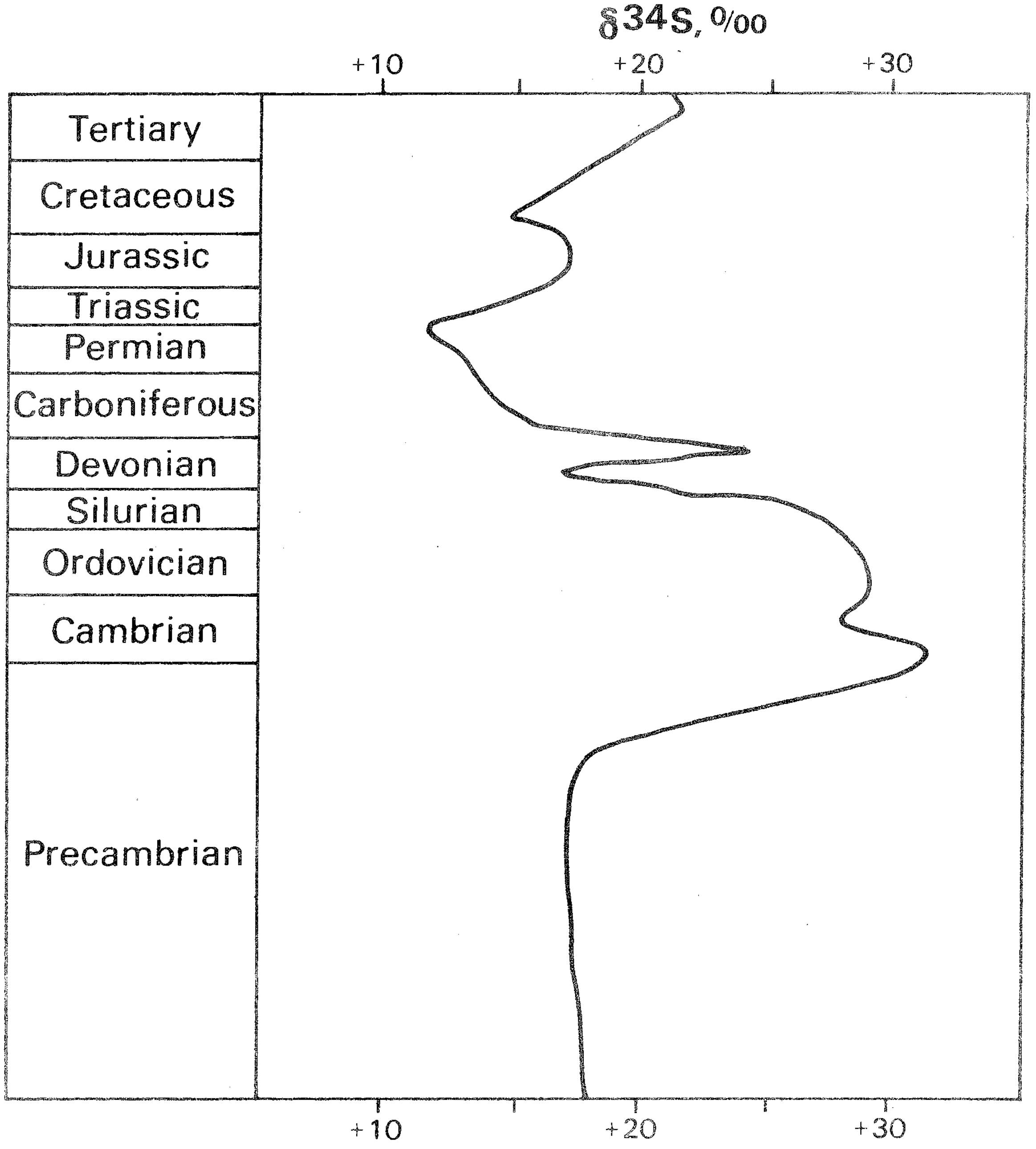

Figure D1 Isotopic variation of sea-water sulphate with time (after Helser, 1977)

lighter than coeval sea-water. They then used this fact to establish the age of some Middle-East oils. Orr (1974) suggested, however, that maturation would alter the isotopic composition of crudes towards heavier values.

ANALYTICAL TECHNIQUES

Reduced sulphur may be present in oil shale samples either as pyrite or in organic compounds. Two different extraction techniques were used in an attempt to differentiate the two sorts of sulphur. For mass-spectrometric analysis sulphur must be in the form of sulphur dioxide and can be prepared directly from the sample, or alternatively by a two stage process in which the sulphur is concentrated first in reduced form and then oxidised. All the sulphur in the rock was extracted by combustion in vacuo with cuprous oxide at 1120° C (Coleman and Moore, 1978). However, this method was difficult to apply in the case of the present samples due to the presence of large quantities of carbonate and organic material. The rapid heating required by the method caused explosive evolution of large amounts of carbon dioxide ejecting the sample from the furnance or, more usually, scattering it throughout the whole system. When a satisfactory combustion did occur it proved difficult to separate the small amounts of sulphur dioxide from the large excess of carbon dioxide. Consequently, only two samples were prepared in this way. These, and the remaining 11 samples, were analysed using a method similar to that described by Thode et al. (1961). The samples were refluxed with a mixture of reducing acids and the resultant hydrogen sulphide was precipitated in cadmium acetate solution. Silver nitrate solution was added to the cadmium sulphide to convert it to silver sulphide which is more readily filtered. The silver sulphide was oxidised with cuprous oxide in vacuo at 1070° C (Robinson and Kusakabe, 1975) using the same apparatus as for the direct extraction.

RESULTS

The sulphur dioxide produced by both pre-treatment processes was analysed isotopically on a V. G. Isotopes Micromass 602-C double collector mass-spectrometer and the results are shown in the table below.

Sample no. (KOS)	$\delta^{34}S$ ‰ Direct extraction total sulphur	Reducing acid method pyrite sulphur
931		-11.9
952		-11.0
953		-15.6
954	-6.9	- 9.0
955	-8.4	-11.9
956		-17.3
957		-21.5
959		+13.6
962		-18.2
963		-16.2
966		-13.6
967		-30.8
969		-23.0

The analytical precision of the mass-spectrometry is about 0.03‰ (2 sigma) but replicate analyses fall within a range which is increased to about 0.3‰ because of the chemical extraction process.

The direct procedure extracts all sulphur in the sample regardless of the original form in which it occurs. It seems likely that the acid reduction method will not attack kerogen sulphur and may not cope with organically bound sulphur either; thus the isotope values relate to the pyrite in the sample. The results for the pyrite are variable, a feature which is typical of sedimentary sulphide in which several diagenetic stages may contribute in varying amounts to the final product.

From the yield of sulphur dioxide it is possible to calculate the approximate content of sulphur. For the two samples which were analysed by both methods it was possible to estimate approximate $\delta^{34}S$ values for the organic sulphur. For samples KOS 954 and 955 these are -5.8 ‰ and -7.5‰ respectively. The sulphur appears to be heavier than that in the pyrite and is within the range reported from crude oils.

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Appendix E:
Potential oil yields by IFP/Rock Eval and modified Fischer assays

Table E1 IFP/Rock Eval analyses

For Type II kerogens a factor of 0.88 has been used to convert the hydrocarbon yield to oil yield
For Type I kerogens, shown *, a conversion factor of 0.90 has been used
Samples representative of a run of bulked core are shown by depth ranges: spot samples are shown by single depths

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
North Runcton Borehole								
12.00 to 12.50	100	4.6	4.1	544	48	408	2.5	2.2
13.00 to 13.50	101	4.2	3.9	529	53	410	2.2	1.9
23.00 to 23.50	102	8.5	3.5	691	34	400	5.9	5.3*
23.50 to 24.00	103	7.4	5.6	328	166	416	2.4	2.1
24.00 to 24.50	104	6.4	3.5	715	39	384	4.6	4.1*
24.50 to 25.00	105	9.8	2.9	682	52	401	6.7	5.9
25.00 to 25.50	106	14.4	3.9	658	36	400	9.5	8.6*
25.50 to 26.00	107	8.5	3.5	452	40	402	3.8	3.3
26.00 to 26.50	108	3.4	3.5	379	54	406	1.3	1.1
30.00 to 30.50	109	4.2	5.7	514	47	402	2.2	1.9
30.50 to 31.00	110	4.2	4.0	560	48	388	2.4	2.1
31.00 to 31.50	111	3.3	2.6	529	48	402	1.7	1.5
33.00 to 33.50	112	5.6	4.1	616	43	397	3.5	3.1
33.50 to 34.00	113	5.6	4.4	529	36	407	3.0	2.7*
35.50 to 36.00	114	7.1	3.2	652	47	400	4.6	4.0
36.00 to 36.50	115	9.9	4.7	646	35	397	6.4	5.8
36.50 to 37.00	116	6.1	3.2	643	54	394	3.9	3.4
37.00 to 37.50	117	4.3	3.6	577	40	406	2.5	2.2
39.00 to 39.50	118	7.1	3.8	609	41	401	4.3	3.9
40.00 to 40.50	119	3.8	3.5	462	97	407	1.8	1.6
45.50 to 46.00	120	4.8	2.1	581	38	422	2.8	2.5
46.00 to 46.50	121	3.0	2.7	473	47	416	1.4	1.2
47.25 to 47.75	122	4.4	3.2	508	39	423	2.2	1.9
47.75 to 48.25	123	4.3	2.4	594	46	422	2.6	2.3
48.25 to 48.75	124	5.7	2.0	614	33	418	3.5	3.2
48.75 to 49.25	125	4.0	2.6	653	37	414	2.6	2.3

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
North Runcton (cont'd)								
49.25 to 49.75	126	4.0	3.3	588	36	427	2.4	2.2
49.75 to 50.25	127	3.0	2.9	400	41	424	1.2	1.1
50.25 to 50.75	128	8.8	2.4	799	27	414	7.0	6.3
50.75 to 51.25	129	4.2	1.7	528	23	424	2.2	2.0
51.25 to 51.75	130	7.7	2.1	928	39	409	7.1	6.4
51.75 to 52.25	131	6.2	3.1	635	34	419	4.2	3.8
52.25 to 52.75	132	3.8	2.9	681	41	428	2.6	2.3
52.75 to 53.25	133	4.2	1.8	691	48	425	2.9	2.6
53.25 to 53.75	134	6.0	2.6	580	38	424	3.5	3.2
53.75 to 54.25	135	5.8	2.0	503	46	421	2.9	2.6
59.50 to 60.00	136	5.0	2.3	537	48	424	2.7	2.4
60.00 to 60.50	137	7.1	2.6	596	37	419	4.2	3.8
62.50 to 63.00	138	5.1	2.3	578	49	424	3.0	2.6
64.00 to 64.50	139	6.2	2.4	526	40	422	3.3	2.9
20.00 to 20.50	655	2.8	2.7	244	45	436	0.7	0.6
20.50 to 21.00	656	1.5	2.3	43	41	430	0.1	0.1
21.00 to 21.50	657	1.0	1.0	64	68	440	0.1	0.1
21.50 to 22.00	658	1.5	1.6	95	38	421	0.1	0.1
22.00 to 22.50	659	1.3	1.0	38	44	439	0.1	-
22.50 to 23.00	660	1.2	1.7	96	50	427	0.1	0.1
26.50 to 27.00	661	3.5	3.1	213	35	430	0.7	0.7
27.00 to 27.50	662	3.0	3.0	63	29	426	0.2	0.2
27.50 to 28.00	663	3.1	2.5	83	33	431	0.3	0.2
28.00 to 28.50	664	4.0	3.4	241	26	419	1.0	0.9
28.50 to 29.00	665	5.0	3.9	196	32	425	0.9	0.8
29.00 to 29.50	666	3.2	2.9	148	107	428	0.5	0.4
29.50 to 30.00	667	3.1	2.6	142	43	423	0.4	0.4
31.50 to 32.00	668	3.3	2.9	305	56	417	1.0	0.9
32.00 to 32.50	669	2.6	3.1	262	41	421	0.7	0.6
32.50 to 33.00	670	3.6	2.1	451	44	417	1.6	1.4
34.00 to 34.50	671	5.9	3.2	411	33	419	2.4	2.1
34.50 to 35.00	672	5.6	2.5	725	36	411	4.0	3.6

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis ° C	Hydrocarbon yield wt%	Oil yield wt%
North Runcton (cont'd)								
35.00 to 35.50	673	5.9	3.5	285	38	419	1.7	1.5
37.50 to 38.00	674	4.9	1.7	539	37	421	2.7	2.4
38.00 to 38.50	675	5.2	3.5	266	27	415	1.4	1.2
38.50 to 39.00	676	5.8	2.6	438	24	417	2.6	2.3
39.50 to 40.00	677	3.7	3.3	314	36	423	1.2	1.0
40.50 to 41.00	678	3.1	3.0	264	35	416	0.8	0.7
41.00 to 41.50	679	5.4	2.8	226	23	427	1.2	1.1
41.50 to 42.00	680	2.5	2.8	190	39	420	0.5	0.4
42.00 to 42.50	681	4.2	3.1	283	27	419	1.2	1.0
42.50 to 43.00	682	4.6	3.2	304	30	423	1.4	1.2
43.00 to 43.50	683	3.8	2.4	284	38	424	1.1	0.9
43.50 to 44.00	684	6.0	2.7	425	57	418	2.5	2.2
44.00 to 44.50	685	3.9	2.7	305	20	418	1.2	1.1
44.50 to 45.00	686	4.3	2.4	355	27	421	1.5	1.3
45.00 to 45.50	687	3.4	2.9	302	58	419	1.0	0.9
46.50 to 47.00	688	4.2	2.4	300	18	420	1.3	1.1
54.50 to 55.00	689	4.1	2.4	312	32	420	1.3	1.1
55.00 to 55.50	690	4.9	2.2	433	44	417	2.1	1.8
55.50 to 56.00	691	2.6	2.3	265	25	419	0.7	0.6
56.00 to 56.50	692	1.3	1.7	205	51	419	0.3	0.2
56.50 to 57.00	693	2.6	1.9	219	27	419	0.6	0.5
57.00 to 57.50	694	2.6	2.3	291	48	415	0.8	0.7
57.50 to 58.00	695	2.3	2.7	510	41	415	1.2	1.0
58.00 to 58.50	696	3.4	2.4	157	29	417	0.5	0.5
58.50 to 59.00	697	3.6	2.8	308	18	414	1.1	1.0
59.00 to 59.50	698	4.7	2.4	440	34	414	2.1	1.8
46.48	803	4.0	1.5	535	78	410	2.2	1.9
48.37	804	7.7	1.8	650	36	427	5.0	4.4
48.96	805	9.3	1.3	881	16	425	8.2	7.2
51.93	900	29.4		839	29	400	24.6	22.2
23.73	932	27.8	1.7	584	20/34	415	17.8	16.0

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
<u>Donington on Bain Borehole</u>								
25.30 to 25.80	140	6.1	4.1	634	34	422	3.9	3.5
25.80 to 26.30	141	5.4	3.2	537	47	421	2.9	2.6
27.55 to 28.05	142	5.4	3.0	659	43	425	3.6	3.2
28.30 to 28.80	143	4.1	2.5	591	60	428	2.4	2.1
32.30 to 32.80	144	3.5	3.4	474	58	425	1.7	1.5
32.80 to 33.30	145	3.1	3.7	412	51	430	1.3	1.1
33.30 to 33.80	146	6.9	4.3	499	35	423	3.5	3.1
43.05 to 43.55	147	12.9	3.0	659	37	431	8.5	7.7
43.55 to 44.05	148	13.1	3.9	659	40	428	8.6	7.7
44.05 to 44.55	149	7.3	3.2	711	41	426	5.2	4.7
44.55 to 45.05	150	6.5	5.1	671	46	418	4.4	4.0
45.05 to 45.55	151	2.2	3.1	512	34	430	1.1	1.0
45.55 to 46.05	152	8.6	4.1	330	43	416	7.2	6.5
63.00 to 63.50	153	4.2	3.8	275	54	416	1.2	1.1
63.50 to 64.00	154	4.2	4.7	565	58	422	2.4	2.1
64.00 to 64.50	155	7.7	3.1	733	43	420	5.6	5.0
64.50 to 65.00	156	9.2	3.8	783	42	423	7.2	6.5
65.00 to 65.50	157	5.7	2.6	698	50	431	4.0	3.6
65.50 to 66.00	158	5.0	4.0	643	60	427	3.2	2.8
66.00 to 66.50	159	6.4	2.9	669	38	425	4.3	3.9
66.50 to 67.00	160	5.4	3.1	969	31	424	5.2	4.7
67.00 to 67.50	161	8.0	3.6	974	13	423	7.8	7.0
67.50 to 68.00	162	7.6	3.6	1034	23	421	7.9	7.1
68.00 to 68.50	163	5.3	4.2	858	27	422	4.5	4.1
68.50 to 69.00	164	7.5	3.5	1103	15	428	8.3	7.5
69.00 to 69.50	165	5.0	2.6	533	23	428	2.6	2.3
82.25 to 82.75	166	4.3	2.0	602	32	426	2.6	2.3
82.75 to 83.25	167	3.9	3.7	461	21	430	1.8	1.6
83.25 to 83.75	168	3.4	4.2	293	23	434	1.0	0.9
83.75 to 84.25	169	3.2	3.1	330	25	433	1.1	1.0
84.25 to 84.75	170	2.8	3.6	265	26	433	0.7	0.6
84.75 to 85.25	171	3.1	2.5	319	24	429	1.0	0.9

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
85.25 to 85.75	172	6.7	2.1	669	19	424	4.2	3.8
85.75 to 86.25	173	5.2	1.7	536	37	425	2.8	2.5
86.25 to 86.75	174	6.6	1.6	633	39	425	4.2	3.8
86.75 to 87.25	175	7.5	1.5	652	38	425	4.9	4.4
87.25 to 87.75	176	3.6	1.9	473	42	424	1.7	1.5
87.75 to 88.25	177	9.2	2.0	543	30	402	5.0	4.5
88.25 to 88.75	178	4.4	1.7	549	45	428	2.4	2.1
88.75 to 89.25	179	7.0	1.6	590	36	419	4.1	3.7
89.25 to 89.75	180	4.7	2.3	352	38	419	1.7	1.5
89.75 to 90.25	181	9.5	2.1	700	32	423	6.7	6.0
90.25 to 90.75	182	10.3	2.1	458		419	4.7	4.3
90.75 to 91.25	183	9.9	2.3	600	33	419	5.9	5.3
91.25 to 91.75	184	14.3	1.5	334	23	416	4.8	4.2
91.75 to 92.25	185	8.4	2.9	561	19	421	4.7	4.2
92.25 to 92.75	186	6.3	2.1	476	39	420	3.0	2.6
92.75 to 93.25	187	6.5	2.8	639	32	421	4.1	3.7
93.25 to 93.75	188	6.5	1.9	615	22	421	4.0	3.6
93.75 to 94.25	189	3.3	2.7	691	115	421	2.3	2.0
94.25 to 94.75	190	5.4	1.8	538	39	425	2.9	2.6
96.75 to 97.25	191	3.6	2.4	366	37	422	1.3	1.2
97.25 to 97.75	192	3.4	2.2	620	60	423	2.1	1.8
97.75 to 98.25	193	3.6	2.2	220	31	423	0.8	0.7
98.25 to 98.75	194	3.8	2.5	437	35	420	1.7	1.5
98.75 to 99.25	195	6.7	3.2	818	43	425	5.5	4.9
99.25 to 99.75	196	6.4	2.2	520	33	424	3.3	3.0
99.75 to 100.25	197	5.3	1.7	427	32	419	2.3	1.9
100.25 to 100.75	198	8.0	2.4	708	46	422	5.6	5.0
100.75 to 101.25	199	6.6	2.2	428	34	420	2.8	2.5
101.25 to 101.75	200	7.8	2.1	477	26	420	3.7	3.3
101.75 to 102.25	201	4.7	2.8	589	53	420	2.8	2.4
102.25 to 102.75	202	4.7	1.8	457	34	420	2.1	1.9
102.75 to 103.25	203	3.6	2.3	392	34	424	1.4	1.2
103.25 to 103.75	204	4.6	2.4	155	53	419	0.7	0.6
103.75 to 104.25	205	6.3	2.2	423	31	421	2.7	2.3

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
Foudry Bridge Borehole								
443.50 to 444.00	629	2.1	6.3	108	20	418	0.2	0.2
444.00 to 444.50	630	3.2	5.3	240	29	423	0.7	0.7
444.50 to 445.00	631	1.5	8.7	103	54	421	0.2	0.1
445.00 to 445.50	632	2.7	1.2	34	20	425	0.1	0.1
445.50 to 446.00	633	14.1	6.4	532	16	412	7.5	6.7
446.00 to 446.50	634	11.1	5.1	500	18	411	5.5	5.0
446.50 to 447.00	635	14.0	6.0	610	20	418	8.5	7.7
447.00 to 447.50	636	13.3	5.2	420	18	414	5.6	5.0
447.50 to 448.00	637	7.4	4.1	509	25	408	3.8	3.4
448.00 to 448.50	638	9.0	6.3	513	86	414	4.6	4.1
448.50 to 449.00	639	7.6	4.4	576	31	419	4.4	4.0
449.00 to 449.50	640	2.4	1.1	261	72	425	0.6	0.5
449.50 to 450.00	641	6.9	3.5	586	31	418	4.1	3.6
450.00 to 450.50	642	7.8	7.4	694	37	415	5.4	4.9
456.00 to 456.50	643	4.4	5.6	242	29	415	1.1	0.9
456.50 to 457.00	644	4.1	4.4	328	28	415	1.3	1.2
457.00 to 457.50	645	3.8	5.5	266	79	421	1.0	0.9
457.50 to 458.00	646	3.5	4.3	239	32	417	0.8	0.7
458.00 to 458.50	647	5.6	6.6	424	41		2.4	2.1
460.00 to 460.50	648	5.4	7.6	486	16	418	2.6	2.4
460.50 to 461.00	649	7.2	3.3	348	32	420	2.5	2.2
463.00 to 463.50	650	17.8	4.6	632	16	408	11.3	10.1
463.50 to 464.00	651	5.0	4.3	548	60	420	2.8	2.4
464.00 to 464.50	652	4.0	3.3	461	14	416	1.8	1.7
464.50 to 465.00	653	6.0	6.5	598	29	419	3.6	3.2
465.00 to 465.50	654	2.9	2.7	321	39	417	0.9	0.8
447.51	1424	35.8	1.4	464	21/22	417	16.6	14.9
447.79	1425	14.1	2.6	616	14	416	8.7	7.8
448.95	1426	10.8	2.8	531	36	416	5.7	5.1
448.37	1427	12.9	0.9	985	12/31	419	12.7	11.4
447.93	1428	20.7	2.9	246	34	417	3.9	3.4
450.11	1429	10.6	3.0	1301	26	411	14.3	12.9

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
450.37	1430	15.7	1.7	563	38	414	3.9	3.4
449.17	1431	10.2	2.2	574	31	408	5.9	5.3
460.88	1432	10.3	2.3	563	38	414	5.8	5.1
461.09	1433	14.4	2.1	599	24	412	8.6	7.8
463.22	1434	21.4	2.1	532	27	413	11.4	10.3
463.78	1435	9.4	1.9	688	29	410	6.4	5.8

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
<u>Marton Borehole</u>								
49.95	700	4.3	3.6	714	6	444	1.5	1.4
56.90	701	7.0	3.3	1120	7	439	3.9	3.5
59.85	702	7.0	3.7	1351	9	436	4.7	4.2
42.20	703	7.3	3.8	1190	6	432	4.3	3.9
34.95	704	9.8	2.3	1475	7	430	7.3	6.5
60.93	705	12.9	2.6	1110	6	432	7.7	7.9
60.81	706	13.4	2.2	1404	11	428	9.4	8.4
63.60	707	14.8	3.0	1401	4	428	10.3	9.3
66.17	708	7.8	2.4	1258	7	425	4.9	4.4
64.10	709	11.9	2.8	1259	6	431	7.5	6.7
47.60	710	12.2	3.3	960	6	439	5.8	5.2
38.35	711	20.1	3.0	1044	4	437	10.5	9.4
38.30	712	11.4	3.5	1089	6	438	6.2	5.6
38.38	713	17.5	3.1	1060	5	436	9.3	8.4
30.25	714	3.3	4.0	475	11	439	0.8	0.7
25.10	715	2.2	3.5	209	6	446	0.2	0.2
32.90	716	27.6	1.5	1138	4	440	15.7	14.1
172.90	717	7.0	2.0	980	4	439	3.4	3.1
161.60	718	10.8	1.8	1111	4	439	6.0	5.4
162.32	719	10.8	2.9	1204	6	439	6.5	5.8
165.53	720	15.8	2.3	823	4	435	6.5	5.8
153.64	721	6.4	2.0	1231	7	438	4.0	3.5
153.25	722	15.1	1.5	588	5	434	4.4	4.0
177.86	723	3.1	2.4	704	7	439	1.1	1.0
176.98	724	6.6	2.9	1029	6	436	3.4	3.1
143.03	725	3.6	2.3	1064	12	439	1.9	1.7
149.22	726	4.3	1.9	973	11	440	2.0	1.8
152.25	727	6.1	2.6	1170	7	439	3.5	3.2
174.03	728	1.3	0	411	85	438	0.3	0.2
167.73	729	3.9	3.2	990	10	438	1.9	1.7
175.98	730	4.7	2.5	1113	6	438	2.6	2.4
158.37	731	14.8	1.9	1069	5	437	7.9	7.1

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
Marton Borehole cont'd								
157.90	732	10.1	2.1	117	5	436	0.6	0.5
144.95	733	10.4	2.2	1160	7	430	6.0	5.4
156.70	734	9.6	1.9	1261	7	439	6.0	5.4
71.03	735	14.9	2.2	990	4	419	7.4	6.6
74.60	736	11.8	2.2	1125	8	420	6.6	6.0
85.40	737	4.4	2.1	1189	10	436	2.6	2.3
79.20	738	17.1	2.1	955	4	434	8.2	7.3
207.50	739	7.2	1.4	1216	10	438	4.4	3.9
211.80	740	15.4	1.6	1072	6	435	8.2	7.4
195.25	741	16.3	2.3	1072	5	423	8.7	7.8
196.60	742	15.6	1.7	800	4	439	6.3	5.6

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
<u>Reighton Borehole</u>								
79.42	743	9.9	1.9	2455	13	421	12.2	10.7
81.08	744	9.4	1.6	1682	12	419	7.9	7.0
81.53	745	11.4	3.0	2024	12	418	11.6	10.2
85.04	746	10.3	2.4	1946	14	420	10.0	8.8
89.61	747	11.6	3.3	1589	18	420	9.2	8.1
90.83	748	7.3	2.7	2573	21	417	9.3	8.2
93.27	749	8.9	1.8	2036	25	415	9.0	7.9
122.45	750	2.7	2.1	850	30	420	11.2	9.9
123.6	751	7.7	2.4	2359	19	418	9.0	7.9
125.04	752	4.4	2.4	1103	14	418	2.5	2.2
124.05	753	17.4	2.2	1627	9	421	14.1	12.4
139.00	754	11.3	1.8	1550	12	420	8.8	7.7
137.00	755	4.3	2.1	848	16	423	1.8	1.6
134.19	756	4.9	2.5	2895	15	414	7.0	6.2
153.85	757	12.8	3.4	2637	19	415	16.9	14.9
144.55	758	12.6	2.7	1876	10	416	11.8	10.4
142.95	759	11.4	2.8	1925	8	418	11.0	9.7
140.36	760	7.9	2.9	1963	12	416	7.7	6.8
157.89	761	7.4	3.1	2489	14	414	9.2	8.1
108.50 to 109.00	769	6.4	3.0	479	16	420	3.1	2.8
109.00 to 109.50	770	4.0	4.1	568	30	419	2.3	2.1
109.50 to 110.00	771	7.0	4.2	294	27	420	2.1	1.8
110.00 to 110.50	772	4.1	4.9	450	16	419	1.8	1.7
110.50 to 111.00	773	5.4	3.5	574	9	420	3.1	2.8
111.00 to 111.50	774	7.2	3.7	489	14	420	3.5	3.2
111.50 to 112.00	775	4.8	2.8	468	13	421	2.3	2.0
112.00 to 112.50	776	8.8	4.3	566	11	421	5.0	4.5
112.50 to 113.00	777	6.9	2.7	383	24	419	2.7	2.4
113.00 to 113.50	778	8.7	2.6	458	8	420	4.0	3.6
113.50 to 114.00	779	4.4	3.3	435	17	420	1.9	1.7
114.00 to 114.50	780	3.9	3.4	882	24	420	3.5	3.1
114.50 to 115.00	781	3.8	3.8	394	15	419	1.5	1.4

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
115.00 to 115.50	782	3.8	3.0	396	20	418	1.5	1.3
116.50 to 117.00	783	3.6	3.9	337	21	419	1.2	1.1
117.00 to 117.50	784	5.8	3.2	473	17	417	2.8	2.5
117.50 to 118.00	785	2.7	3.3	171	40	419	0.5	0.4
118.00 to 118.50	786	2.7	3.2	245	24	422	0.7	0.6
119.00 to 119.50	787	4.2	4.4	458	13	419	1.9	1.7
119.50 to 120.00	788	6.0	2.6	339	23	420	2.0	1.8
120.00 to 120.50	789	4.3	2.0	288	12	418	1.2	1.1
120.50 to 121.00	790	7.2	4.0	547	19	420	3.9	3.5
121.00 to 121.50	791	4.6	4.3	359	29	417	1.7	1.5
121.50 to 122.00	792	4.6	4.8	391	28	422	1.8	1.6

Table E.2 Modified Fischer Assay analyses

* indicates specific gravity estimated as 0.92 n.m. ... not measured

Borehole and depth (m)	Sample No. (KOS)	Laramie sample No. (SBR 79)	Yield in wt %				Yield in US gal/ US ton		Specific gravity of oil at 60° /60° F	Tendency to coke
			Oil	Water	Spent Shale	Gas loss	Oil	Water		
Encombe										
116.25 to 118.25 m	1700	1xa	6.0	3.0	88.4	2.6	14.9	7.2	0.966	None
		1xb	6.3	3.3	87.3	3.1	15.5	7.9	0.971	None
118.25 to 120.25 m	1701	2xa	7.3	3.5	84.9	4.3	17.7	8.4	0.988	None
		2xb	7.7	4.0	84.8	3.5	18.9	9.6	0.985	None
120.25 to 122.25 m	1702	3xa	7.2	4.2	85.3	3.3	17.5	10.1	0.990	None
		3xb	4.6	5.0	88.0	2.4	11.1	12.0	0.990	None
122.25 to 124.25 m	1703	4xa	5.5	3.7	87.9	2.9	13.5	8.9	0.982	None
		4xb	5.4	3.7	88.1	2.8	13.3	8.9	0.964	None
124.25 to 126.25 m	1704	5xa	3.6	3.5	90.4	2.5	9.1	8.4	0.960	None
		5xb	3.4	3.7	90.7	2.2	8.4	8.9	0.978	None
126.25 to 127.75 m	1705	6xa	3.6	3.5	90.5	2.4	9.0	8.4	0.963	None
		6xb	3.6	3.5	89.9	3.0	8.8	8.4	0.964	None
Donington on Bain										
43.05 to 44.55 m	1706	7xa	6.4	5.0	85.2	3.4	16.0	12.0	0.959	None
		7xb	5.8	6.5	84.0	3.7	14.3	15.6	0.967	None
44.55 to 46.05 m	1707	8xa	1.7	6.0	90.0	2.3	4.4*	14.4		None
		8xb	1.5	6.0	90.3	2.2	3.9*	14.4		None
Portesham										
47.74 to 49.74 m	1708	9xa	4.9	7.0	85.0	3.1	11.9	16.8	0.990	None
		9xb	4.7	7.0	85.1	3.2	11.3	16.8	0.988	None
49.74 to 51.74 m	1709	10xa	5.0	7.5	84.6	2.9	12.0	18.0	1.000	None
		10xb	5.1	7.4	84.5	3.0	12.2	17.7	1.003	None

Table E.2 cont'd

Borehole and depth (m)	Sample No. (KOS)	Laramie sample No. (SBR 79)	Yield in wt %				Yield in US gal/ US ton		Specific gravity of oil at 60°/60° F	Tendency to coke
			Oil	Water	Spent Shale	Gas loss	Oil	Water		
Portesham										
51.74 to 53.74 m	1710	11xa	2.8	6.0	89.3	1.9	6.9	14.4	0.979	None
		11ab	2.7	6.1	89.2	2.0	6.7	14.6	0.979	None
Encombe										
77.75 to 79.75 m	1711	12xa	4.0	4.5	89.3	2.2	9.7	10.8	0.981	None
		12xb	5.1	4.5	87.4	3.0	12.3	10.8	0.987	None
79.75 to 81.75 m	1712	13xa	2.8	2.9	92.5	1.8	7.0	7.0	0.953	None
		13xb	2.9	3.3	91.7	2.1	7.2	7.9	0.956	None
North Runcton										
23.00 to 24.50 m	1713	14xa	5.1	5.8	85.2	3.9	12.6	13.9	0.975	None
		14xb	5.1	5.8	85.6	3.5	12.5	13.9	0.975	None
23.00 to 24.50 m	1714	15xa	5.1	6.0	85.2	3.7	12.2	14.4	1.006	None
		15xb	5.1	5.8	85.2	3.9	12.2	13.9	1.003	None
35.50 to 37.50 m	1715	16xa	3.0	5.5	88.4	3.1	7.5	13.2	0.976	None
		16xb	2.9	5.6	88.4	3.1	7.2	13.4	0.976	None
50.25 to 52.25 m	1716	17xa	3.4	5.0	88.7	2.9	8.4	12.0	0.978	None
		17xb	3.1	4.7	89.4	2.8	7.6	11.3	0.971	None
Donington on Bain										
64.00 to 65.50 m	1717	18xa	2.3	7.0	88.0	2.7	5.7	16.8	0.968	None
		18xb	2.3	7.0	87.7	3.0	5.8	16.8	0.969	None
64.00 to 65.50 m	1718	19xa	1.6	6.0	90.6	1.8	4.1*	14.4	n. m.	None
		19xb	1.4	6.9	89.5	2.2	3.7*	16.5	n. m.	None
67.00 to 69.00 m	1719	20xa	2.5	7.0	88.2	2.3	6.2	16.8	0.953	None
		20xb	2.6	6.5	88.6	2.3	6.6	15.6	0.951	None

Table E.2 cont'd

Borehole and depth (m)	Sample No. (KOS)	Laramie sample No. (SBR 79)	Yield in wt %				Yield in US gal/ US ton		Specific gravity of oil at 60° /60° F	Tendency to coke
			Oil	Water	Spent Shale	Gas loss	Oil	Water		
Encombe										
84.75 to 86.75 m	1920	21xa	3.7	3.4	90.3	2.6	9.2	8.1	0.965	None
		21xb	4.0	4.0	89.3	2.7	10.0	9.6	0.964	None
Donington on Bain										
89.25 to 91.25 m	1721	22xa	3.9	4.6	89.0	2.5	9.5	11.0	0.974	None
		22xb	3.9	4.7	88.8	2.6	9.7	11.3	0.973	None
91.25 to 93.25 m	1722	23xa	4.0	5.0	87.8	3.2	10.0	12.0	0.975	None
		23xb	3.8	5.5	87.9	2.8	9.3	13.2	0.975	None
Portesham										
150.74 to 152.74 m	1723	24xa	5.3	7.0	84.6	3.1	12.9	16.8	0.987	None
		24xb	4.3	7.8	84.2	3.7	10.5	18.7	0.989	None
143.24 to 145.24 m	1724	25xa	2.1	7.0	88.7	2.2	5.2	16.8	0.964	None
		25xb	2.3	7.5	87.5	2.7	5.8	18.0	0.968	None
176.24 to 178.24 m	1725	26xa	4.0	6.0	86.2	3.8	9.8	14.4	0.979	None
		26xb	4.5	6.0	86.6	2.9	11.0	14.4	0.978	None
180.74 to 182.74 m	1726	27xa	1.9	8.0	88.0	2.1	4.8*	19.2		None
		27xb	2.7	7.5	87.3	2.5	6.7	18.0	0.973	None
West Lavington										
156.00 to 158.00 m	1727	28xa	4.2	5.5	87.2	3.1	10.3	13.2	0.979	None
		28xb	4.4	5.3	87.0	3.3	10.7	12.7	0.980	None
Foudry Bridge										
445.50 to 447.50 m	1728	29xa	4.1	13.5	79.0	3.4	10.1	32.4	0.986	None
		29xb	4.1	13.5	78.8	3.6	9.8	32.4	0.992	None
447.50 to 449.50 m	1729	30xa	1.7	8.5	87.7	2.1	4.3*	20.4	n.m.	None
		30xb	1.1	8.5	87.8	2.6	3.0*	20.4	n.m.	None

Table E.2 cont'd

Borehole and depth (m)	Sample No. (KOS)	Laramie sample No. (SBR 79)	Yield in wt %				Yield in US gal/ US ton		Specific gravity of oil at 60° /60° F	Tendency to coke
			Oil	Water	Spent Shale	Gas loss	Oil	Water		
<u>Kimmeridge Bay</u>										
41.75 to 42.75 m	1730	31xa	2.8	4.0	91.0	2.2	7.1	9.6	0.956	None
		31xb	4.5	4.5	88.0	3.0	11.2	10.8	0.972	None
45.75 to 47.75 m	1731	32xa	2.9	4.2	90.5	2.4	7.3	10.1	0.963	None
		32xb	2.8	4.5	90.4	2.3	7.0	10.8	0.958	None
47.75 to 49.75 m	1732	33xa	2.6	4.7	90.4	2.3	6.6	11.3	0.960	None
		33xb	2.7	4.5	90.1	2.7	6.7	10.8	0.960	None
<u>Tisbury</u>										
154.75 to 156.25 m	1733	34xa	4.7	6.0	86.0	3.3	11.3	14.4	0.998	None
		34xb	4.9	6.1	85.7	3.3	11.7	14.6	0.998	None
168.75 to 170.25 m	1734	35xa	1.8	6.3	89.8	2.1	4.8*	15.1	n. m.	None
		35xb	1.6	6.5	90.0	1.9	4.1*	15.6	n. m.	None
228.75 to 230.75 m	1735	36xa	4.8	7.5	84.2	3.5	11.8	18.0	0.985	None
		36xb	5.0	7.0	83.9	4.1	12.2	16.8	0.985	None
233.75 to 235.75 m	1736	37xa	3.0	7.5	87.4	2.1	7.6	18.0	0.965	None
		37xb	3.2	8.2	86.0	2.6	7.9	19.7	0.971	None
<u>Reighton</u>										
108.50 to 110.50 m	1737	38xa	0.8	7.9	89.3	2.0	2.0*	18.9	n. m.	None
		38xb	0.8	7.8	89.8	1.6	2.0*	18.7	n. m.	None
110.50 to 112.50 m	1738	39xa	1.6	6.8	89.8	1.8	4.0*	16.3	n. m.	None
		39xb	1.9	7.0	89.1	2.0	5.0*	16.8	n. m.	None
112.50 to 114.50 m	1739	40xa	2.0	6.3	89.7	2.0	4.9	15.1	0.963	None
		40xb	2.0	6.0	89.7	2.3	5.0	14.4	0.961	None

Appendix F:
Major, minor and trace element analyses

Table F1 Major element analyses: concentrations of oxides in wt%

*unreliable where $SiO_2 > 50\%$ †unreliable where $SiO_2 < 30\%$

Depth (m)	Sample no. (KOS)	Loss on ignition to 450° C wt%	Organic carbon wt%	MgO	Al_2O_3	SiO_2*	K_2O	CaO†	TiO_2	Fe_2O_3
North Runcton Borehole										
23.00 to 23.50	102	37.5	8.5	1.0	9.6	31.8	1.7	6.7	0.54	3.5
23.50 to 24.00	103	26.1	7.4	1.2	15.5	40.1	2.0	8.2	0.68	4.8
24.00 to 24.50	104	9.9	6.4	1.1	13.2	35.1	2.0	13.2	0.74	5.6
24.50 to 25.00	105	14.1	9.8	1.1	13.2	35.0	1.7	12.6	0.94	3.3
25.00 to 25.50	106	15.9	14.4	1.1	11.4	32.4	1.8	10.2	0.77	4.5
25.50 to 26.00	107	9.0	8.5	1.1	11.8	35.4	2.0	11.8	1.01	4.6
26.00 to 26.50	108	4.2	3.4	1.4	19.3	49.5	2.6	7.6	0.97	7.0
30.00 to 30.50	109	6.5	4.2	1.3	22.0	51.5	2.4	6.7	0.80	4.8
30.50 to 31.00	110	6.6	4.2	1.2	14.3	45.7	2.6	6.6	0.93	4.4
31.00 to 31.50	111	5.0	3.3	1.1	11.3	34.3	2.7	10.6	0.91	4.0
Donington on Bain Borehole										
43.05 to 43.55	147	15.8	12.9	1.2	16.1	36.5	2.4	9.3	0.78	4.8
43.55 to 44.05	148	12.5	13.1	1.1	13.2	36.3	2.2	9.4	0.92	4.8
44.05 to 44.55	149	6.2	7.3	1.3	17.0	44.9	2.6	9.5	0.90	5.5
44.55 to 45.05	150	10.7	6.5	1.2	18.3	44.4	2.8	8.3	0.84	4.8
45.05 to 45.55	151	4.1	2.2	1.6	18.4	52.1	3.3	7.5	0.85	5.5
45.55 to 46.05	152	13.0	8.6	1.2	13.9	42.7	2.6	6.0	0.76	5.1
Portesham Borehole										
44.74 to 45.24	243	11.9	8.3	1.2	20.6	52.7	3.3	2.9	0.77	6.0
45.24 to 45.74	244	11.7	12.9	1.2	17.4	51.4	2.7	1.4	1.03	6.1
45.74 to 46.24	245	12.5	15.8	0.8	11.2	34.2	1.9	9.0	0.95	4.9
46.24 to 46.74	246	4.1	12.3	1.0	19.8	50.4	2.6	3.4	1.57	7.1
47.74 to 48.24	243	9.3	9.0	0.8	10.9	34.2	1.9	12.3	0.77	4.3
48.24 to 48.74	248	14.0	9.7	0.8	11.0	35.1	2.1	10.3	0.71	4.1
48.74 to 49.24	249	17.1	14.5	0.8	14.6	41.8	1.8	7.9	0.99	4.7

Depth (m)	Sample no. (KOS)	Loss on ignition to 450° C wt%	Organic carbon wt%	MgO	Al_2O_3	SiO_2*	K_2O	CaO†	TiO_2	Fe_2O_3
49.24 to 49.74	250	10.6	9.3	0.9	12.4	36.8	2.2	11.6	0.90	3.9
49.74 to 50.24	251	13.8	12.9	0.9	14.8	46.8	1.7	6.3	0.90	5.4
50.24 to 50.74	252	3.4	5.5	1.1	15.2	57.7	2.2	5.0	1.05	5.7
50.74 to 51.24	253	14.7	18.0	0.8	17.7	40.8	2.1	5.7	1.02	6.0
52.24 to 52.74	254	14.3	6.4	1.1	13.7	45.8	3.2	5.5	0.70	5.2
52.74 to 53.24	255	13.0	8.1	1.2	14.7	49.3	3.9	5.2	0.73	6.4
53.24 to 53.74	256	19.7	11.9	1.1	14.0	41.8	3.0	6.0	0.64	5.7
53.74 to 54.24	257	12.2	7.2	1.0	11.8	43.4	2.9	6.5	0.82	6.0
54.24 to 54.74	258	10.6	5.8	0.9	9.2	40.9	3.2	8.0	0.78	6.5
62.74 to 63.24	259	6.0	4.8	3.0	10.9	44.0	2.5	6.8	0.88	5.7
63.24 to 63.74	260	11.7	5.7	0.9	12.9	55.7	2.8	5.5	0.83	4.4
63.74 to 64.24	261	9.6	5.5	1.0	15.4	53.5	3.3	4.9	0.85	4.1
64.24 to 64.74	262	8.0	4.1	1.1	17.1	56.3	3.5	5.8	0.88	4.9
68.24 to 68.74	263	13.8	8.1	1.0	16.0	47.7	3.0	6.8	0.82	4.8
68.74 to 69.24	264	4.7	3.5	1.6	18.6	60.9	3.5	5.3	0.78	5.8
69.24 to 69.74	265	8.5	5.6	1.4	15.7	52.7	2.5	8.0	0.69	4.7
69.74 to 70.24	266	4.0	1.8	1.8	14.5	62.1	3.1	6.4	0.82	5.3
72.24 to 72.74	267	10.7	4.9	0.8	14.9	58.6	2.6	1.9	0.85	4.3
72.74 to 73.24	268	17.4	9.1	0.9	15.0	49.3	2.3	6.8	0.77	4.5
73.24 to 73.74	269	5.9	2.6	0.9	17.1	70.4	2.9	1.3	0.99	4.9
73.74 to 74.24	270	5.6	2.8	0.8	14.5	67.9	2.8	2.3	0.81	4.2
74.24 to 74.74	271	8.3	5.0	0.9	17.0	67.3	2.8	3.0	0.87	5.3
76.74 to 77.24	272	3.2	2.3	0.8	13.6	69.5	3.0	1.0	0.99	4.7
77.24 to 77.74	273	8.3	4.9	0.8	15.8	63.7	2.4	1.4	0.84	4.4
77.74 to 78.24	274	8.4	4.8	0.9	17.0	64.6	3.0	0.6	0.98	4.9
78.24 to 78.74	275	10.2	5.1	0.9	20.2	66.7	2.7	0.8	0.88	4.6
78.74 to 79.24	276	9.6	7.1	1.0	17.8	58.3	3.0	1.5	0.87	5.2
79.24 to 79.74	277	10.8	5.8	0.8	13.1	56.3	2.3	3.2	0.77	4.9
79.74 to 80.24	278	11.3	6.9	1.0	16.4	59.6	2.4	3.6	0.85	5.7
80.24 to 80.74	279	8.9	5.5	1.0	11.2	51.1	2.3	7.1	0.76	5.2
89.74 to 90.24	280	8.0	6.8	1.1	16.7	50.0	2.5	5.4	0.78	5.7
90.24 to 90.74	281	11.5	6.5	1.2	16.4	53.6	2.4	4.8	0.86	6.2
92.74 to 93.24	282	8.8	4.6	0.9	14.4	56.7	2.4	3.5	0.86	5.5

Depth (m)	Sample no. (KOS)	Loss on ignition to 450° C wt%	Organic carbon wt%	MgO	Al_2O_3	SiO_2*	K_2O	CaO†	TiO_2	Fe_2O_3
93.24 to 93.74	283	7.9	4.5	0.9	17.4	55.0	2.4	4.1	0.81	5.4
93.74 to 94.24	284	12.0	7.1	1.1	14.3	47.0	2.7	5.2	0.94	5.8
94.24 to 94.74	285	6.8	4.0	1.0	17.1	57.1	3.4	3.3	0.79	5.1
96.74 to 97.24	287	5.6	4.1	1.1	18.6	63.9	2.8	2.5	0.81	6.0
97.24 to 97.74	288	7.9	4.8	1.1	16.7	60.0	2.6	4.4	0.81	5.3
101.24 to 101.74	289	7.8	6.4	1.2	21.4	58.7	2.8	2.7	0.95	5.2
101.74 to 102.24	290	8.2	5.6	1.1	16.7	52.8	3.3	2.8	0.83	6.5
102.24 to 102.74	291	6.1	4.7	0.9	15.5	61.4	3.8	1.6	0.78	5.2
102.74 to 103.24	292	11.0	6.2	0.8	8.3	34.6	1.5	6.6	0.78	3.3
103.24 to 103.74	294	6.7	3.5	0.8	14.3	58.2	2.7	0.5	0.94	4.6
103.74 to 104.24	295	12.0	7.9	0.9	13.3	47.0	2.1	3.2	0.85	7.1
104.24 to 104.74	297	10.5	6.3	1.0	16.1	52.5	2.7	4.6	0.79	5.8
104.74 to 105.24	298	2.9	2.6	0.8	15.3	66.5	2.6	0.6	1.04	4.3
115.24 to 115.74	299	7.7	4.4	0.9	14.6	50.1	2.5	2.7	0.77	5.3
115.74 to 116.24	300	14.3	7.3	1.2	15.1	45.9	3.3	6.7	0.88	7.2
116.24 to 116.74	301	9.7	6.0	1.2	18.0	52.4	2.9	3.8	0.87	6.1
116.74 to 117.24	302	10.6	6.2	0.8	11.1	40.1	2.3	5.6	0.78	4.6
121.74 to 122.24	303	5.1	3.3	1.1	14.0	55.4	2.9	3.9	0.72	3.9
122.24 to 122.74	305	8.5	7.0	1.1	13.5	46.3	2.5	5.1	0.78	5.2
122.74 to 123.24	306	7.7	5.7	1.2	23.1	61.7	3.2	3.7	0.85	6.6
123.24 to 123.74	307	7.2	5.4	1.1	16.6	56.8	2.6	3.7	0.71	4.9
123.74 to 124.24	308	6.5	5.3	1.4	20.8	63.9	4.2	4.5	0.83	7.3
124.24 to 124.74	309	5.0	3.0	1.0	16.3	66.0	2.8	3.2	0.86	4.9
124.74 to 125.24	310	6.5	4.4	1.0	18.4	65.0	2.7	1.6	0.87	4.9
125.24 to 125.74	311	12.5	8.4	1.1	13.2	53.2	2.5	5.7	0.88	6.6
128.24 to 128.74	312	9.4	6.3	1.3	18.4	57.0	2.8	5.7	0.79	5.8
128.74 to 129.24	313	7.8	5.7	1.2	19.7	54.5	2.7	7.3	0.95	6.3
129.24 to 129.74	314	4.7	4.7	0.7	4.6	37.3	1.8	4.3	0.81	3.8
129.74 to 130.24	315	9.6	4.6	1.3	21.7	61.5	3.7	1.9	0.86	6.4
130.24 to 130.74	316	7.8	4.2	1.4	19.7	59.5	3.7	7.0	0.82	6.0
130.74 to 131.24	317	10.4	7.4	1.3	19.4	57.0	3.0	5.9	0.83	6.6
131.24 to 131.74	319	8.6	4.9	1.3	21.2	67.5	4.0	2.3	0.96	5.6
131.74 to 132.24	320	9.4	5.2	1.2	21.6	56.3	3.6	4.6	0.82	6.7
132.24 to 132.74	321	12.5	9.5	3.1	19.4	43.1	2.2	9.5	0.76	7.2

Depth (m)	Sample no. (KOS)	Loss on ignition to 450° C wt%	Organic carbon wt%	MgO	Al_2O_3	SiO_2*	K_2O	CaO†	TiO_2	Fe_2O_3
<u>Miscellaneous Samples</u>										
Setchey excavation Trench B	801	34.6	15.8	0.7	8.6	20.7	1.6	9.3	0.70	2.3
Clavell's Hard Blackstone	802	47.5	23.5	0.5	4.6	12.7	0.9	9.4	0.47	2.8
North Runcton B 46.48 to 46.49	803	6.9	4.0	1.3	22.1	51.2	2.6	6.4	0.88	6.1
North Runcton B 48.37 to 48.40	804	12.9	7.7	1.8	19.0	49.5	2.4	11.0	0.85	4.3
North Runcton B 48.96 to 48.98	805	20.0	9.3	1.4	15.0	38.7	2.3	15.4	0.61	5.1
Portesham 153.79 to 153.83	806	12.7	7.1	1.7	8.7	27.4	1.6	12.4	0.61	8.0
Portesham 152.74 to 152.80	807	2.0	2.6	1.7	17.8	47.9	3.0	12.7	0.96	4.8
Portesham 51.30 to 51.35	808	36.2	19.0	0.5	7.6	19.1	1.0	9.3	0.69	3.5
Portesham 50.46 to 50.52	809	5.2	4.9	1.1	20.0	60.7	2.7	5.3	0.95	5.3
Portesham 53.25 to 53.28	810	22.9	18.4	0.5	3.9	15.0	0.8	8.8	0.45	6.6

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
104.25 to 104.75	206	8.0	3.1	489	26	420	0.4	0.4
104.75 to 105.25	207	2.7	1.8	182	45	420	0.5	0.4
105.25 to 105.75	208	5.3	1.9	528	36	416	2.8	2.5
105.75 to 106.25	209	9.6	2.6	455	19	422	4.4	3.9
46.43	933	22.6	2.8	683	17	406	15.8	13.9
46.90	1605	12.8		117	28	410	1.5	1.1
72.75	1608	11.7		458	26	416	5.3	4.8
71.60	1610	13.7		431	32	419	5.9	5.3
73.26	1611	12.1		486	36	417	6.9	6.2
74.32	1612	8.0		425	35	415	3.4	3.1
44.77	1613	14.2		604	28	412	8.6	7.7
44.17	1614	17.7		681	24	417	12.1	10.9
43.83	1615	16.6		783	206	417	12.5	11.3
33.64	1617	22.7		672	23/49	420	15.2	13.7
34.18	1618	12.2		585	35	413	7.1	6.4
32.46	1619	5.5		66	21	411	0.4	0.4
33.86	1620	16.3		610	25	419	10.0	9.0

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis ° C	Hydrocarbon yield wt %	Oil yield wt %
<u>Portesham Borehole</u>								
44.74 to 45.24	243	8.3	3.2				3.8	3.4
45.24 to 45.74	244	12.9	2.5				5.8	5.2
45.74 to 46.24	245	15.8	2.3				5.3	4.7
46.24 to 46.74	246	12.3	1.2				4.9	4.5
47.74 to 48.24	247	9.0	2.7				5.4	4.9
48.24 to 48.74	248	9.7	2.3				6.0	5.4
48.74 to 49.24	249	14.5	2.8				7.2	6.5
49.24 to 49.74	250	9.3	2.5				5.1	4.5
49.74 to 50.24	251	12.9	2.1				6.6	5.9
50.24 to 50.74	252	5.5	2.9				2.9	2.6
50.74 to 51.24	253	18.0	2.7				7.6	6.5
52.24 to 52.74	254	6.4	2.6				3.9	3.4
52.74 to 53.24	255	8.1	2.4				5.3	4.8
53.24 to 53.74	256	11.9	2.8				7.0	6.3
53.74 to 54.24	257	7.2	0.7				5.0	4.5
54.24 to 54.74	258	5.8	2.0				3.4	3.0
62.74 to 63.24	259	4.8	1.7				2.7	2.3
63.24 to 63.74	260	5.7	1.8				3.4	3.0
63.74 to 64.24	261	5.5	2.1				3.1	2.7
64.24 to 64.74	262	4.1	2.6				2.1	1.8
68.24 to 68.74	263	8.1	1.9				6.5	5.9
68.74 to 69.24	264	3.5	2.7				1.7	1.5
69.24 to 69.74	265	5.6	2.2				3.4	1.3
69.74 to 70.24	266	1.8	1.1				0.7	0.6
72.24 to 72.74	267	4.9	1.7				2.2	1.9
72.74 to 73.24	268	9.1	1.6				4.9	4.3
73.24 to 73.74	269	2.6	1.9				0.8	0.7
73.74 to 74.24	270	2.8	1.5				1.4	1.2
74.24 to 74.74	271	5.0	2.2				3.0	2.6
76.74 to 77.24	272	2.3	1.2				0.7	0.6
77.24 to 77.74	273	4.9	2.6				2.8	2.5
77.74 to 78.24	274	4.8	1.6				2.5	2.3

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis ° C	Hydrocarbon yield wt %	Oil yield wt %
Portesham Borehole cont'd								
78.24 to 78.74	275	5.1	1.3				2.7	2.4
78.74 to 79.24	276	7.1	1.7				4.3	3.9
79.24 to 79.74	277	5.8	1.2				3.5	3.1
79.74 to 80.24	278	6.9	1.8				4.2	3.8
80.24 to 80.74	279	5.5	1.7				3.4	3.1
89.74 to 90.24	280	6.8	1.6				4.3	3.9
90.24 to 90.74	281	6.5	1.8				4.0	3.6
92.74 to 93.24	282	4.6	2.1				2.0	1.8
93.24 to 93.74	283	4.5	2.0	437	30	424	2.0	1.7
93.74 to 94.24	284	7.1	2.1	466	21	416	3.3	3.0
94.24 to 94.74	285	4.0	1.9	458	34	418	1.8	1.6
96.74 to 97.24	287	4.1	1.7	380	29	416	1.5	1.4
97.24 to 97.74	288	4.8	1.0	381	28	411	1.8	1.6
101.24 to 101.74	289	6.4	1.2	407	21	409	2.6	2.3
101.74 to 102.24	290	5.6	1.9	503	29	419	2.8	2.5
102.24 to 102.74	291	4.7	1.8	388	20	415	1.8	1.6
102.74 to 103.24	292	6.2	1.3	574	24	409	3.6	3.2
103.24 to 103.74	294	3.5	2.0	312	1	420	1.1	1.0
103.74 to 104.24	295	7.9	1.4	549	13	418	4.4	3.9
104.24 to 104.74	297	6.3	2.1	514	21	414	3.2	2.9
104.74 to 105.24	298	2.6	1.9	258	22	418	0.7	0.6
115.24 to 115.74	299	4.4	1.4	397	21	417	1.7	1.5
115.74 to 116.24	300	7.3	2.0	716	39	416	5.2	4.6
116.24 to 116.74	301	6.0	1.5	504	26	414	3.0	2.7
116.74 to 117.24	302	6.2	1.6	489	26	417	3.0	2.7
121.74 to 122.24	303	3.3	2.3	281	32	419	0.9	0.8
122.24 to 122.74	305	7.0	1.3	536	21	413	3.8	3.4
122.74 to 123.24	306	5.7	1.6	435	19	418	2.5	2.2
123.24 to 123.74	307	5.4	1.8	462	18	418	2.5	2.2
123.74 to 124.24	308	5.3	1.7	454	19	418	2.4	2.2
124.24 to 124.74	309	3.0	2.3	448	25	417	1.3	1.2
124.74 to 125.24	310	4.4	2.1	456	18	416	2.0	1.8

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
Portesham Borehole cont'd								
125.24 to 125.74	311	8.4	1.5	1109	9	414	9.3	8.3
128.24 to 128.74	312	6.3	1.8	544	20	416	3.4	3.1
128.74 to 129.24	313	5.7	2.4	189	32	413	1.1	0.9
129.24 to 129.74	314	4.7	2.2	217	39	419	1.0	0.9
129.74 to 130.24	315	4.6	2.7	380	33	410	1.7	1.5
130.24 to 130.74	316	4.2	1.6	416	34	415	1.8	1.5
130.74 to 131.24	317	7.4	1.9	430	28	416	3.2	2.8
131.24 to 131.74	319	4.9	2.3	371	21	411	1.8	1.6
131.74 to 132.24	320	5.2	2.6	308	19	422	1.6	1.4
132.24 to 132.74	321	9.5	1.8	411	17	418	3.9	3.4
132.74 to 133.24	322	5.1	2.4	489	22	418	2.5	2.2
133.24 to 133.74	323	7.0	1.6	427	26	416	3.0	2.6
133.74 to 134.24	324	4.5	1.7	396	21	418	1.8	1.6
134.24 to 134.74	325	5.3	2.1	399	27	425	2.1	1.8
134.74 to 135.24	326	4.9	1.5	474	29	425	2.3	2.0
135.24 to 135.74	327	5.2	2.0	470	27	417	2.5	2.1
135.74 to 136.24	328	4.4	1.6	498	40	421	2.2	1.9
136.24 to 136.74	329	5.3	1.9	456	27	424	2.4	2.1
136.74 to 137.24	330	4.2	2.3	447	20	420	1.9	1.6
137.24 to 137.74	331	5.1	1.2	513	29	422	2.6	2.3
137.74 to 138.24	332	3.7	2.2	253	25	426	0.9	0.8
138.24 to 138.74	333	5.2	3.5	406	21	427	2.1	1.8
138.74 to 139.24	334	4.4	2.8	415	15	426	1.8	1.6
139.24 to 139.74	335	3.3	3.2	251	25	454	0.3	0.7
139.74 to 140.24	336	5.5	3.3	538	23	426	2.9	2.6
140.24 to 140.74	337	7.5	3.7	424	25	422	3.2	2.8
140.74 to 141.24	338	5.9	4.4	251	33	424	1.5	1.3
141.24 to 141.74	339	8.9	2.4	558	27	426	5.0	4.4
141.74 to 142.24	340	5.1	3.9	295	30	427	1.5	1.3
142.24 to 142.74	341	7.2	4.0	481	21	428	3.5	3.1
142.74 to 143.24	342	4.7	3.5	455	21	428	2.1	1.8
143.24 to 143.74	343	7.5	3.5	561	22	428	4.2	3.7

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis wt %	Hydrocarbon yield wt %	Oil yield wt %
Portesham Borehole cont'd								
143.74 to 144.24	344	7.0	2.9	555	15	429	3.9	3.4
144.24 to 144.74	345	7.2	4.8	572	22	418	4.1	3.6
144.74 to 145.24	346	7.2	2.6	584	22	422	4.2	3.7
145.24 to 145.74	347	8.0	3.1	518	18	425	4.1	3.1
145.74 to 146.24	348	8.8	3.3	445	17	424	3.9	3.4
146.24 to 146.74	349	5.5	4.7	432	19	429	2.4	2.1
146.74 to 147.24	350	7.5	2.5	412	15	428	3.1	2.7
147.24 to 147.74	351	5.5	4.5	349	23	427	1.7	1.7
147.74 to 148.24	352	5.1	4.4	265	24	420	1.4	1.2
148.24 to 148.74	353	8.4	3.4	562	34	419	4.7	4.1
148.74 to 149.24	354	9.2	3.0	570	27	421	5.3	4.7
149.24 to 149.74	355	12.3	2.9	241	20	422	3.0	2.6
149.74 to 150.24	356	6.0	3.1	222	26	424	1.3	1.1
150.24 to 150.74	357	4.6	3.1	576	29	426	2.7	2.4
150.74 to 151.24	358	9.3	2.9	532	27	424	4.9	4.3
151.24 to 151.74	359	9.6	3.7	579	21	422	5.6	4.9
151.74 to 152.24	360	11.8	4.5	632	28	421	7.5	6.6
152.24 to 152.74	361	11.9	4.4	579	25	420	6.9	6.1
152.74 to 153.24	362	6.7	3.3	480	24	421	3.2	2.8
153.24 to 153.74	363	7.6	5.2	477	26	422	3.6	3.2
174.24 to 174.74	364	7.3	4.0	464	16	420	3.4	3.0
174.74 to 175.24	365	3.1	1.6	501	32	416	1.6	1.4
175.24 to 175.74	366	2.7	1.1	507	26	423	1.3	1.1
175.74 to 176.24	367	5.2	2.9	469	32	423	2.4	2.1
176.24 to 176.74	368	11.0	2.6	572	20	422	6.3	5.5
176.74 to 177.24	369	7.2	3.4	577	34	423	4.2	3.7
177.24 to 177.74	370	9.2	4.3	538	26	422	5.0	4.4
177.74 to 178.24	371	10.3	3.0	561	26	425	5.8	5.1
178.74 to 179.24	372	5.8	3.9	556	33	420	3.2	2.8
179.24 to 179.74	373	6.9	3.9	604	31	420	4.2	3.7
179.74 to 180.24	374	6.2	4.2	555	29	422	3.5	3.1
180.24 to 180.74	375	7.1	3.7	583	30	423	4.2	3.7

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
Portesham Borehole cont'd								
180.74 to 181.24	376	5.7	3.4	494	33	425	2.8	2.5
181.24 to 181.74	377	7.6	2.9	574	27	423	4.3	3.8
181.74 to 182.24	378	7.0	3.7	529	29	423	3.7	3.2
182.24 to 182.74	379	8.7	2.7	547	22	423	4.8	4.2
184.24 to 184.74	380	7.6	3.6	509	17	425	3.9	3.4
184.74 to 185.24	381	10.2	2.9	531	20	423	5.4	4.7
185.49 to 185.99	382	8.7	4.2	516	14	422	4.5	4.0
185.99 to 186.49	383	4.6	4.9	376	25	429	1.7	1.5
51.24 to 51.74	767	10.5	2.3	583	12	415	6.1	5.5
51.74 to 52.24	768	3.7	2.4	400	35	420	1.5	1.3
153.79	806	7.1	2.2	769	38	422	5.4	4.4
152.74	807	2.6	1.9	265	71	430	0.7	0.6
51.30	808	19.0	1.6	401	26/57	410	7.6	6.7
50.46	809	4.9	1.7	372	19	417	1.8	1.6
53.25	810	18.4	1.6	775	31	419	14.2	12.0
125.43	901	8.9					8.2	7.4
153.74	902	8.6					7.0	6.3
142.33	1320	8.5	1.8	699	47	419	5.9	5.3
142.21	1321	7.5	1.9	638	51	415	4.8	4.2
135.36	1322	8.8	2.2	621	29	419	5.5	4.9
134.56	1323	7.7	1.7	621	39	413	4.8	4.3
132.65	1324	10.1	1.5	631	29	415	6.4	5.7
132.51	1325	5.8	0.8	705	25	420	4.1	3.7
129.61	1326	10.2	1.5	643	37	417	6.6	5.9
128.49	1327	11.2	2.5	604	26	423	6.7	6.1
125.96	1328	11.7	2.2	660	27	418	7.7	6.9
126.45	1329	9.6	2.0	700	23	420	6.7	6.0
125.41	1330	9.4	2.3	621	40	419	5.8	5.3
122.36	1331	8.6	2.4	698	32	424	5.6	5.0
124.12	1332	9.5	1.3	676	44	411	6.4	5.8
145.83	1333	12.1	1.6	583	35	419	7.1	6.4
145.69	1334	26.5	2.5	704	13	415	18.7	16.8

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distilate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
Portesham Borehole cont'd								
148.86	1335	8.7	1.0	732	43	411	6.4	5.7
151.03	1336	11.6	1.9	636	37	417	7.4	6.7
151.23	1337	15.8	2.4	658	17	419	10.4	9.4
152.57	1338	33.4	2.1	582	16	421	19.4	17.5
152.05	1339	17.6	2.3	644	31	416	11.4	10.2
153.79	1340	11.5	1.3	580	15	413	6.7	6.0
177.17	1341	13.5	1.4	680	18	411	9.2	8.3
181.25	1342	7.3	1.9	620	24	418	4.5	4.1
182.58	1343	9.0	2.2	737	9	416	6.6	6.0
183.94	1344	9.6	1.8	635	26	420	6.1	5.5
184.94	1345	23.4	2.2	702	21	421	16.4	14.8
104.24	1346	12.1	2.5	424	24	417	5.1	4.6
134.27	1347	9.3	2.0	589	27	416	5.5	4.9
94.39	1348	6.5	1.6	593	29	420	3.8	3.5
90.34	1349	8.2	2.1	461	36	419	3.8	3.3
80.40	1350	5.4	1.5	452	41	421	2.4	2.1
72.97	1351	16.8	2.4	605	35	423	10.2	9.1
53.64	1352	12.1	1.8	614	29	422	7.5	6.7
54.06	1353	9.1	1.0	935	44	417	6.3	5.7
51.32	1354	37.0	2.2	250	11	413	9.3	8.4
45.99	1355	10.6	1.3				7.2	6.5

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
<u>Encombe Borehole</u>								
62.25 to 62.75	384	4.9	2.3				1.7	1.5
62.75 to 63.25	385	4.4	2.8				1.5	1.3
63.25 to 63.75	386	3.8	2.5				0.9	0.8
63.75 to 64.25	387	4.7	2.4				1.6	1.4
64.25 to 64.75	388	4.2	2.6				1.6	1.4
64.75 to 65.25	389	3.9	4.4				2.0	1.8
65.25 to 65.75	390	6.8	2.1				5.1	4.5
65.75 to 66.25	391	7.1	1.7				3.5	3.1
66.75 to 67.25	393	7.3	1.5				1.8	1.6
67.25 to 67.75	394	7.4	1.7				3.4	3.1
77.25 to 77.75	395	8.7	1.7				3.9	3.4
77.75 to 78.25	396	11.6	2.7				6.0	5.3
78.25 to 78.75	397	3.2	3.7				8.5	7.5
78.75 to 79.25	398	11.4	2.3				6.0	5.3
79.25 to 79.75	399	13.9	1.4				7.3	6.4
79.75 to 80.25	400	7.5	1.6				4.5	4.0
80.25 to 80.75	401	4.6	1.1				2.6	2.3
80.75 to 81.25	402	5.6	1.3				2.7	2.4
81.25 to 81.75	403	9.1	1.8				4.9	4.3
81.75 to 82.25	404	7.4	1.3				4.0	3.5
82.25 to 82.75	405	5.1	1.7				1.9	1.7
82.75 to 83.25	406	5.0	2.0				2.1	1.8
82.25 to 83.75	407	6.5	1.8				3.2	2.8
83.75 to 84.25	408	4.4	2.4				1.7	1.5
84.25 to 84.75	409	8.5	2.2				2.1	1.8
84.75 to 85.25	410	7.4	3.3				4.4	3.9
85.25 to 85.75	411	7.5	2.9				4.2	3.7
85.75 to 86.25	412	7.8	2.5				5.9	5.2
86.25 to 86.75	413	8.6	1.1				5.2	4.6
86.75 to 87.25	414	3.8	2.8				1.7	1.5
114.25 to 114.75	415	14.7	1.5				10.6	9.3
116.25 to 116.75	416	13.0	1.1				7.7	6.9

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
Encombe Borehole cont'd								
116.75 to 117.25	417	11.7	1.2				9.2	8.2
117.25 to 117.75	418	7.4	1.1				5.6	5.1
117.75 to 118.25	419	13.0	2.1				8.0	7.0
118.25 to 118.75	420	19.9	1.8	571	12	428	11.4	10.0
118.75 to 119.25	421	11.9	2.3	580	17	424	6.9	6.1
119.25 to 119.75	422	18.9	2.0	134	6	426	2.5	2.2
119.75 to 120.25	423	9.2	3.4	141	10	425	1.3	1.1
120.75 to 121.25	424	4.5	2.7	394	29	427	1.8	1.6
121.25 to 121.75	425	11.3	1.7	690	23	428	7.8	7.0
121.75 to 122.25	426	22.2	1.4	160	11	429	3.6	3.1
122.25 to 122.75	427	13.2	2.5	646	12	425	8.5	7.5
122.75 to 123.25	428	5.3	1.7	532	10	425	2.8	2.5
123.25 to 123.75	429	6.6	2.7	649	13	427	4.3	3.8
123.75 to 124.25	430	18.2	1.6	558	10	428	10.2	9.0
124.25 to 124.75	431	9.6	2.1	587	11	428	5.6	4.9
124.75 to 125.25	432	8.2	3.6	436	13	424	3.6	3.2
125.25 to 125.75	433	10.2	1.6	619	13	426	6.3	5.5
125.75 to 126.25	434	5.5	2.2	444	15	430	2.6	2.3
126.25 to 126.75	435	7.3	2.4	486	10	426	3.5	3.1
126.75 to 127.25	436	11.3	1.3	657	16	422	7.4	6.5
127.25 to 127.75	437	4.0	2.0	894	28	434	3.6	3.2
131.25 to 131.75	438	10.5	2.1	503	18	429	5.3	4.7
131.75 to 132.25	439	11.5	1.8	434	9	431	5.0	4.4
61.75 to 62.25	763	6.4	1.9	539	20	417	3.5	3.1
66.25 to 66.75	764	4.3	2.6	363	25	419	1.6	1.4
120.25 to 120.75	766	4.3	3.1	419	12	415	1.8	1.6
66.02	1403	18.1	2.3	467	12	410	8.5	7.6
66.36	1404	5.4	1.3	546	24	415	2.9	2.6
67.60	1405	8.1	1.2	505	16	410	4.1	3.7
77.89	1406	25.6	0.8	86	8	417	2.2	2.0
77.36	1407	3.5	0.9	430	27	419	1.5	1.3
76.99	1408	7.1	1.2	637	17	418	4.5	4.1

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	
<u>Encombe Borehole cont'd</u>								
79.48	1409	9.8	0.3	489	12	415	4.8	4.3
79.12	1410	13.8	0.4	487	12	414	6.7	6.0
80.15	1411	8.5	0.5	579	18	417	4.9	4.4
84.44	1412	3.7	0.4	463	34	419	1.7	1.5
84.56	1413	5.1	0.5	533	27	413	2.7	2.4
85.85	1414	9.0	0.8	566	23	415	5.1	4.6
84.69	1415	7.4	1.8	535	17	420	4.0	3.6
86.40	1416	8.9	1.5	594	26	421	5.3	4.7
114.75	1417	32.0	0.9	302	13	421	9.7	8.7
114.57	1418	28.5	0.8	293	11	411	8.3	7.5
117.55	1419	11.2	1.0	710	21	417	7.9	7.1
118.58	1420	27.1	1.6	543	4	418	14.7	13.2
122.35	1421	30.1	0.7	593	9	419	18.1	16.3
123.35	1422	31.5	0.8	229	10	417	7.2	6.5
126.78	1423	7.8	0.5	632	20	42	5.0	4.5

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
Kimmeridge Bay Borehole								
31.25 to 31.75	440	3.1	2.2	1064	17	431	1.6	1.4
31.75 to 32.25	441	6.7	2.1	1372	7	426	4.5	4.0
32.25 to 32.75	442	10.9	2.4	1125	5	421	6.1	5.4
32.75 to 33.25	443	7.0	1.8	1473	8	423	5.1	4.5
33.25 to 33.75	444	7.8	2.4	1524	10	422	5.9	5.2
33.75 to 34.25	445	2.7	2.3	743	17	424	1.0	0.9
34.25 to 34.75	446	6.0	2.5	1235	10	428	3.7	3.3
34.75 to 35.25	447	5.2	2.4	1114	13	428	2.9	2.5
35.25 to 35.75	448	4.1	1.7	462	33	424	1.9	1.7
35.75 to 36.25	449	6.0	1.5	169	20	429	1.0	0.9
36.25 to 36.75	450	3.1	2.3	1142	63	437	3.6	3.2
36.75 to 37.25	451	6.0	1.9	630	59	429	3.8	3.3
37.25 to 37.75	452	5.0	1.9	457	22	423	2.3	2.1
37.75 to 38.25	453	3.2	2.0	455	28	424	1.5	1.3
38.25 to 38.75	454	6.1	1.8	632	29	429	3.8	3.5
38.75 to 39.25	455	1.8	2.1	282	58	430	0.5	0.5
39.25 to 39.75	456	3.0	1.7	320	37	420	0.9	0.9
39.75 to 40.25	457	5.2	1.3	539	23	432	2.8	2.5
40.25 to 40.75	458	6.2	1.7	645	23	419	4.0	3.6
40.75 to 41.25	459	4.0	2.1	581	42	426	2.3	2.0
41.25 to 41.75	460	2.6	1.8	428	30	421	1.1	1.0
41.75 to 42.25	461	8.7	3.0	744	29	428	6.5	5.8
42.25 to 42.75	462	8.3	1.8	678	15	419	5.6	5.0
42.75 to 43.25	463	9.0	2.7	217	12	425	2.0	1.8
43.25 to 43.75	464	5.5	2.0	558	23	418	3.1	2.8
43.75 to 44.25	465	4.0	2.8	563	32	430	2.3	2.0
44.25 to 44.75	466	7.7	2.5	620	15	425	4.8	4.3
44.75 to 55.25	467	3.8	1.4	572	43	428	2.2	1.9
45.25 to 45.75	468	3.2	1.7	462	45	429	1.3	1.1
45.75 to 46.25	469	7.0	1.8	634	22	427	4.4	4.0
46.25 to 46.75	470	5.0	1.5	610	32	431	3.1	2.8
46.75 to 47.25	471	5.4	1.9	677	21	428	3.6	3.3

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis ° C	Hydrocarbon yield wt%	Oil yield wt%
Kimmeridge Bay Borehole cont'd								
47.25 to 47.75	472	7.6	1.6	581	18	420	4.4	4.0
47.75 to 48.25	473	5.3	1.9	603	26	431	3.2	2.9
48.25 to 48.75	474	6.2	2.0	670	22	421	4.2	3.8
48.75 to 49.25	475	3.8	1.5	638	35	432	2.4	2.2
49.25 to 49.75	476	8.4	1.9	544	18	424	4.6	4.1
49.75 to 50.25	477	5.7	1.8	572	26	430	3.3	2.9
50.25 to 50.75	478	3.4	2.7	379	11	426	1.4	1.3
50.75 to 51.25	479	6.9	1.8	566	21	427	3.9	3.5
51.25 to 51.75	480	4.7	3.0	422	20	423	2.0	1.7
51.75 to 52.25	481	5.1	1.8	609	39	426	3.1	2.8
52.25 to 52.75	482	4.9	2.1	633	21	425	3.1	2.8
52.75 to 53.25	483	4.1	2.3	455	6	432	1.9	1.7
53.25 to 53.75	484	5.4	2.7	610	21	424	3.3	3.0
53.75 to 54.25	485	5.2	2.8	567	9	430	2.9	2.7
54.25 to 54.75	486	5.0	3.2	436	9	426	2.2	2.0
54.75 to 55.25	487	6.0	1.7	599	7	434	3.6	3.3
56.75 to 57.25	488	7.8	2.0	1317	12	428	5.1	4.5
57.25 to 57.75	489	11.0	1.7	1284	12	426	7.0	6.2
57.75 to 58.25	490	6.6	2.4	1145	18	425	3.8	3.3
61.25 to 61.75	491	10.6	3.0	1329	11	428	7.0	6.2
61.75 to 62.25	492	8.8	2.3	1212	9	429	5.3	4.7
66.75 to 67.25	493	5.3	2.4	1127	20	424	3.0	2.6
67.25 to 67.75	494	5.3	1.7	1162	18	424	3.0	2.6
67.75 to 68.25	495	11.8	1.5	1425	13	424	8.4	7.4
68.25 to 68.75	496	13.8	1.6	1888	10	422	13.0	11.4
68.75 to 69.25	497	10.2	1.9	1622	12	424	8.3	7.3
70.25 to 70.75	500	11.7	1.4	1252	20	426	7.3	6.4
70.75 to 71.25	501	12.7	1.4	1353	17	427	8.6	7.6
71.25 to 71.75	502	15.1	1.5	1278	15	426	9.6	8.5
71.75 to 72.25	503	13.4	1.8	1522	27	425	10.2	9.0
72.75 to 73.25	505	4.7	1.2	1217	41	423	2.9	2.6
73.25 to 73.75	506	5.6	1.7	1057	26	422	3.0	2.6

Depth (m)	Sample no. (KOS)	Organic carbon wt%	Aqueous distillate wt%	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt%	Oil yield wt%
Kimmeridge Bay Borehole cont'd								
83.25 to 83.75	507	5.2	2.7	1421	14	428	3.7	3.3
83.75 to 84.25	508	3.9	1.7	1144	27	426	2.2	1.9
104.25 to 104.75	509	6.2	3.4	1906	20	426	5.9	5.2
104.75 to 105.25	510	8.4	2.1	1903	13	424	7.9	6.9
108.25 to 108.75	511	10.1	1.8	1823	23	426	9.2	8.1
108.75 to 109.25	512	10.2	2.4	1631	14	422	8.3	7.3
54.88	930	8.3	2.1	614	12	427	5.1	4.6
108.53	931	18.3	1.8	603	9	409	11.0	9.9
67.92	1387	15.5	0.8	763	11	426	11.8	10.6
44.28	1388	10.1	1.6	699	10	417	7.1	6.4
42.21	1389	14.9	1.3	637	10	418	9.5	8.5
39.78	1390	8.4	0.8	878	16	419	7.3	6.6
32.61	1391	11.3	1.4	781	12	415	8.9	8.0
33.36	1392	8.5	1.3	625	16	414	5.3	4.8
35.90	1393	15.6	1.5	750	14	420	11.7	10.5
37.28	1394	8.8	1.4	729	19	419	6.4	5.8
46.46	1395	10.8	0.8	656	17	420	7.1	6.4
70.55	1397	15.0	1.3	590	13	419	8.8	7.9
70.75	1398	20.8	1.6	569	11	419	11.8	10.6
70.85	1399	22.1	1.4	544	10	420	12.0	10.8
71.09	1400	23.7	0.7	461	8	417	10.9	9.8
71.50	1401	30.1	1.0	557	8	422	16.8	15.1
72.10	1402	27.5	1.1	439	9	419	12.1	10.8

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
<u>Tisbury Borehole</u>								
139,25 to 139,75	514	4,5	3,6	418	43	431	1,9	1,7
139,75 to 140,25	515	4,8	2,4	423	48	425	2,0	1,8
154,75 to 155,25	516	15,2	2,2	338	9	414	5,1	4,6
155,25 to 155,75	517	5,1	2,0	453	44	411	2,3	2,0
155,75 to 156,25	518	8,2	2,7	578	35	414	4,7	4,2
156,25 to 156,75	519	5,7	2,4	274	25	415	1,6	1,4
156,75 to 157,25	520	5,8	3,5	519	36	415	3,0	2,7
157,25 to 157,75	521	5,5	3,4	303	21	417	1,7	1,5
165,25 to 165,75	522	2,8	1,7	317	48	412	0,9	0,8
165,75 to 166,25	523	5,6	3,6	289	20	422	1,6	1,4
166,25 to 166,75	524	5,1	4,2	587	39	409	3,0	2,6
166,75 to 167,25	525	7,4	3,8	356	26	416	2,6	2,3
167,25 to 167,75	526	3,5	4,0	381	27	426	1,3	1,2
167,75 to 168,28	527	3,7	3,8	315	33	410	1,2	1,0
168,25 to 168,75	528	3,3	5,0	138	22	426	0,5	0,4
168,75 to 169,25	529	6,2	3,2	534	39	415	3,3	2,9
169,25 to 169,75	530	7,1	3,2	675	40	417	4,8	4,3
169,75 to 170,25	531	4,8	3,5	504	20	420	2,4	2,2
173,75 to 174,25	532	5,5	3,7	650	37	414	3,6	3,2
174,25 to 174,75	533	5,9	3,4	513	36	407	3,0	2,7
175,75 to 176,25	534	3,2	4,8	383	42	414	0,9	0,8
176,25 to 176,75	535	5,0	2,0	558	22	431	2,8	2,5
176,75 to 177,25	536	5,9	3,3	474	26	414	2,8	2,5
177,25 to 177,75	537	5,6	3,1	326	27	417	1,8	1,6
177,75 to 178,25	538	6,1	4,9	425	28	416	2,6	2,3
178,25 to 178,75	539	3,8	5,8	306	33	416	1,2	1,0
178,75 to 179,25	540	3,9	5,4	297	39	426	1,2	1,0
179,25 to 179,75	541	3,5	3,9	433	44	427	1,5	1,3
179,75 to 180,25	542	4,5	3,7	295	28	420	1,3	1,2
180,25 to 180,75	543	3,9	3,3	481	39	426	1,9	1,7
180,75 to 181,25	544	3,5	4,0	302	33	419	1,1	0,9
181,25 to 181,75	545	3,4	2,9	384	54	428	1,3	1,1

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
Tisbury borehole cont'd								
193.75 to 194.25	546	3.8	3.1	354	37	420	1.3	1.2
217.25 to 217.75	547	3.7	3.1	425	41	421	1.6	1.4
217.75 to 218.25	548	3.3	2.9	437	39	423	1.4	1.3
211.75 to 212.25	549	4.6	5.2	483	38	422	2.2	2.0
212.25 to 212.75	550	3.0	6.5	379	42	419	1.1	1.0
212.75 to 213.25	551	5.2	3.9	371	33	425	1.9	1.7
213.25 to 213.75	552	2.8	4.5	175	29	420	0.5	0.4
213.75 to 214.25	553	3.2	6.1	245	29	432	0.8	0.7
214.25 to 214.75	554	4.6	4.2	431	28	421	2.0	1.8
214.75 to 215.25	555	5.6	3.0	490	36	430	2.8	2.4
215.25 to 215.75	556	3.7	3.1	303	34	426	1.1	0.9
215.75 to 216.25	557	2.3	4.5	146	46	428	-	-
216.25 to 216.75	558	4.7	3.6	398	38	431	1.9	1.6
216.75 to 217.25	559	2.4	4.4	229	60	427	0.6	0.5
219.25 to 219.75	560	3.2	3.8	350	51	430	1.1	1.0
219.75 to 220.25	561	3.6	4.7	294	41	429	1.1	0.9
220.25 to 220.75	562	6.4	3.6	632	43	419	4.0	3.5
220.75 to 221.25	563	4.2	4.9	523	48	418	2.2	1.9
221.25 to 221.75	564	3.5	6.3	338	38	429	1.2	1.0
221.75 to 222.25	565	7.9	4.2	263	58	417	2.1	1.8
222.25 to 222.75	566	5.4	4.3	452	52	422	2.4	2.1
222.75 to 223.25	567	4.8	5.7	388	45	427	1.9	1.6
223.25 to 223.75	568	4.3	5.2	345	62	420	1.5	1.3
228.75 to 229.25	569	7.0	3.7	443	22	431	3.1	2.8
229.25 to 229.75	570	9.1	3.7	549	39	429	5.0	4.4
229.75 to 230.25	571	6.5	5.2	503	40	418	3.3	2.9
230.25 to 230.75	572	10.1	2.9	563	31	422	5.7	5.1
230.75 to 231.25	573	9.9	3.0	669	51	414	6.6	5.8
231.25 to 231.75	574	4.6	5.8	431	33	424	2.6	1.7
231.75 to 232.25	575	7.5	5.5	574	46	415	4.3	3.8
323.25 to 232.75	576	6.9	3.3	459	19	425	3.2	2.8
232.75 to 233.25	577	4.6	4.4	497	54	413	2.3	2.0

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
<u>Tisbury borehole cont'd</u>								
233.25 to 233.75	578	7.1	3.3	519	35	420	3.7	3.2
233.75 to 234.25	579	10.7	3.6	653	54	419	7.0	6.2
234.25 to 234.75	580	8.5	3.0	557	40	421	4.7	4.2
234.75 to 235.25	581	12.6	3.2	564	39	415	7.1	6.3
235.25 to 235.75	582	10.6	3.3	756	33	421	8.0	7.2
256.75 to 257.25	583	7.1	3.2	248	42	418	1.8	1.5
257.25 to 257.75	584	6.8	3.7	585	43	422	3.9	3.4
257.75 to 258.25	585	11.0	4.1	561	41	416	6.2	5.4
258.25 to 258.75	586	3.7	5.0	329	28	428	1.2	1.1
258.75 to 259.25	587	5.9	5.7	436	30	421	2.6	2.3
222.75 to 223.25	588	3.0	3.5	260	45	432	0.8	0.7
223.25 to 223.75	589	6.8	3.6	442	27	420	3.0	2.7
223.75 to 224.25	590	3.9	3.5	334	33	429	1.3	1.1
224.25 to 224.75	591	3.9	3.0	312	42	419	1.2	1.1
224.75 to 225.25	592	7.8	3.1	468	42	427	3.6	3.2
225.25 to 225.75	593	5.3	3.4	407	37	415	2.1	1.9
225.75 to 226.25	594	4.3	4.3	395	22	429	1.7	1.5
226.25 to 226.75	595	5.0	4.7	399	32	416	2.0	1.8
226.75 to 227.25	596	4.4	3.3	449	35	428	2.0	1.7
227.25 to 227.75	597	4.5	3.4	281	49	418	1.3	1.1
227.75 to 228.25	598	4.8	5.2	562	33	431	2.7	2.4
228.25 to 228.75	599	4.8	3.8	294	58	422	1.4	1.2
228.75 to 229.25	600	5.2	3.5	403	33	428	2.1	1.9
229.25 to 229.75	601	5.5	5.0	468	42	426	2.6	2.3
218.25 to 218.75	602	1.7	2.9	219	61	421	0.4	0.3
218.75 to 219.25	699	4.2	3.5	305	56	417	1.7	1.5
222.01	1356	7.7	5.6	614	3	416	4.7	4.2
257.95	1357	26.6	3.3	782	23	419	20.0	18.0
257.20	1358	16.7	3.7	550	28	416	9.2	8.3
256.45	1359	9.8	4.0	646	35	413	6.3	5.7
235.52	1360	21.0	4.3	761	19	421	16.0	14.4
235.40	1361	12.3	3.5	610	23	416	7.5	6.8

Depth (m)	Sample no. (KOS)	Organic carbon wt %	Aqueous distillate wt %	Hydrogen Index	Oxygen Index	Temp. of max. rate of pyrolysis °C	Hydrocarbon yield wt %	Oil yield wt %
Tisbury borehole cont'd								
235.23	1362	15.8	1.6	949	26	420	15.0	13.5
234.67	1363	13.3	3.9	619	2	415	8.2	7.4
231.85	1364	24.0	6.3	830	21	421	20.0	18.0
234.19	1365	10.4	4.7	444	29	421	4.6	4.0
233.95	1366	8.2	6.5	1747	62	413	14.4	12.6
233.57	1367	16.9	1.8	324	28	414	5.5	4.8
230.57	1368	19.3	3.0	438	35	417	8.5	7.4
223.79	1369	5.0	6.8	437	36	420	2.2	1.9
229.85	1370	9.2	3.8	524	15	419	4.8	4.3
225.70	1371	5.8	2.3	547	29	422	3.2	2.8
224.79	1372	10.4	5.5	663	34	416	6.9	6.0
193.96	1374	4.4	2.8	510	31	417	2.3	2.0
177.03	1375	12.0	3.5	530	30	413	6.4	5.6
174.26	1376	9.8	2.5	840	25	419	8.3	7.3
169.46	1377	14.7	2.3	165	18	420	2.4	2.1
156.81	1378	16.2	2.1	745	25	417	12.1	10.6
155.24	1379	22.9	3.2	759	27	418	17.4	15.3
155.05	1380	22.1	6.6	547	34	407	12.1	10.6
154.78	1381	21.5	3.6	655	56	416	14.1	12.4
166.85	1436	13.2	4.4	639	31	416	8.4	7.6
157.31	1437	18.6	5.6	535	21/13	415	10.0	9.0

Table F2 Elemental analyses of Kimmeridge Clay oil shales and oil shale/mudstone mixtures

All samples (total 100)

ELEMENT	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MAXIMUM VALUE	MINIMUM VALUE	NUMBER OF DETERMINATIONS
IN	777.660	86.424	11.1	952.00	400.00	100
EU	712.820	93.452	13.1	936.00	357.00	100
RT	587.120	103.806	17.6	756.00	300.00	100
LI	49.922	6.981	13.9	58.10	23.10	100
BE	2.089	2.181	104.3	19.80	0.30	100
B	223.880	62.770	28.0	344.00	68.00	100
MGO	1.105	0.371	33.6	3.07	0.47	100
AL2O3	15.319	3.902	25.4	23.10	3.90	100
SIO2	49.553	12.142	24.5	70.40	12.70	100
K2O	2.600	0.637	24.5	4.27	0.79	100
CAO	5.895	3.285	55.7	15.44	0.49	100
TIO2	0.836	0.133	15.9	1.57	0.45	100
V	117.010	34.976	29.8	226.00	57.00	100
CR	78.440	14.686	18.7	108.00	30.00	100
MN	128.490	44.325	34.4	196.00	0.00	100
FE2O3	5.243	1.038	19.7	8.04	2.28	100
CO	8.580	2.495	29.0	22.00	3.00	100
NI	51.250	16.489	32.1	103.00	19.00	100
CU	37.450	10.096	26.9	70.00	20.00	100
ZN	140.480	86.372	61.4	622.00	27.00	100
GA	15.258	3.609	23.6	21.60	4.30	100
GE	1.100	1.982	180.2	8.00	0.00	100
RB	195.750	51.682	26.4	328.00	68.00	100
SR	291.230	75.491	25.9	680.00	158.00	100
Y	32.700	8.689	26.5	65.00	21.00	100
ZR	198.040	104.689	52.8	456.00	33.00	100
MO	16.620	35.905	216.0	269.00	0.00	100
AG	0.221	0.555	250.1	4.10	0.00	100
SN	0.540	1.452	268.9	7.00	0.00	100
BA	248.860	48.325	19.4	339.00	94.00	100
LA	55.230	13.868	25.1	107.00	26.00	100
PB	7.980	5.063	63.4	25.00	0.00	100
BI	1.560	3.098	198.6	20.00	0.00	100
LI2	77.090	23.821	30.9	134.00	23.00	100
MN2	0.011	0.017	151.7	0.04	0.00	100
PB2	9.810	20.340	207.3	132.00	0.00	100
B1	603.880	66.759	11.0	770.00	396.00	100
B2	440.990	93.092	21.1	862.00	273.00	100
B3	373.160	87.358	23.4	771.00	235.00	100
K/RB	111.470	14.686	13.1	151.00	73.00	100

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RECALC. OMITTING SAMPLES OUTSIDE RANGE MEAN PLUS OR MINUS TWICE STD DEV
100 KIMMERIDGE OIL SHALES


     ELEMENT          MEAN        STANDARD    COEFFICIENT OF    MAXIMUM       MINIMUM      NUMBER OF
                                  DEVIATION     VARIATION        VALUE         VALUE    DETERMINATIONS

     IN             784.177        70.376          8.9          945.00        626.00          96
     EU             718.927        78.224         10.8          877.00        574.00          96
     PT             600.789        86.898         14.4          756.00        399.00          95
     LI              50.943         4.955          9.7           58.10         36.70          96
     BE               1.851         1.108         59.8            6.10          0.30          98
     B              228.319        58.280         25.5          344.00        101.00          97
     MGO              1.065         0.251         23.5            1.78          0.47          98
     AL2O3           15.659         3.437         21.9           23.10          7.60          97
     SIO2            50.915        10.314         20.2           70.40         27.40          96
     K2O              2.609         0.518         19.8            3.83          1.50          94
     CAO              5.580         2.945         52.7           12.42          0.49          96
     TIO2             0.839         0.095         11.3            1.05          0.61          96
     V              114.257        31.625         27.6          182.00         57.00          97
     CR              79.395        12.686         15.9          103.00         51.00          96
     MN             139.663        23.662         16.9          196.00         74.00          97
     FE2O3            5.248         0.915         17.4            7.24          3.33          96
     CO               8.315         1.782         21.4           13.00          5.00          95
     NI              49.052        13.631         27.7           84.00         19.00          95
     CU              36.385         8.768         24.0           57.00         20.00          96
     ZN             176.536        57.257         45.2          304.00         27.00          95
     GA              15.462         3.344         21.6           21.60          8.20          98
     GE               0.688         1.318        191.6            5.00          0.00          93
     RB             194.634        42.964         22.0          294.00        100.00          93
     SR             285.000        60.926         21.3          430.00        158.00          98
     Y               31.095         5.982         19.2           46.00         21.00          94
     ZR             187.843        93.747         49.9          399.00         33.00          96
     MO              10.302        11.325        109.9           83.00          0.00          96
     AG               0.134         0.283        211.2            1.20          0.00          96
     SN               0.088         0.440        495.8            3.00          0.00          90
     BA             255.452        39.373         15.4          339.00        154.00          95
     LA              54.333        11.867         21.8           82.00         30.00          96
     PB               7.546         4.467         59.2           18.00          0.00          97
     BI               1.114         2.015        180.7            7.00          0.00          96
     LI2             75.904        20.571         27.1          117.00         35.00          94
     MN2              0.011         0.017        151.7            0.04          0.00         100
     PB2              6.347        12.284        193.5           48.00          0.00          95
     B1             602.831        55.888          9.2          732.00        490.00          95
     B2             426.747        68.628         16.0          619.00        273.00          95
     B3             359.894        64.591         17.9          532.00        235.00          95
     K/RB           111.126        12.712         11.4          138.00         85.00          95
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14 ORGANIC RICH SAMPLES

ELEMENT	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MAXIMUM VALUE	MINIMUM VALUE	NUMBER OF DETERMINATIONS
IN	848.500	70.792	8.3	952.00	750.00	14
EU	723.785	74.440	10.2	871.00	630.00	14
PT	482.642	113.728	23.5	733.00	316.00	14
LI	44.199	11.248	25.4	57.10	23.10	14
BE	1.492	0.963	64.5	3.30	0.30	14
B	166.000	68.955	41.5	250.00	68.00	14
MGO	0.874	0.238	27.2	1.23	0.47	14
AL2O3	12.485	4.881	39.0	19.80	3.90	14
SIO2	34.278	12.800	37.3	51.40	12.70	14
K2O	1.870	0.675	36.1	2.95	0.79	14
CAO	7.506	2.625	34.9	10.16	1.37	14
TIO2	0.848	0.280	33.0	1.57	0.45	14
V	162.642	24.462	15.0	196.00	112.00	14
CR	73.071	24.253	33.1	108.00	30.00	14
MN	92.500	43.406	46.9	138.00	0.00	14
FE2O3	4.932	1.386	28.1	7.12	2.28	14
CO	9.285	4.581	49.3	22.00	3.00	14
NI	68.000	15.191	22.3	101.00	49.00	14
CU	46.642	12.200	26.1	70.00	25.00	14
ZN	208.071	142.674	68.5	622.00	80.00	14
GA	11.057	3.196	28.9	16.10	4.30	14
GE	0.000	0.000	0.0	0.00	0.00	14
RB	133.214	40.681	30.5	217.00	68.00	14
SR	332.500	117.449	35.3	680.00	211.00	14
Y	40.642	8.837	21.7	61.00	29.00	14
ZR	110.571	46.248	41.8	222.00	47.00	14
MO	63.428	78.482	123.7	269.00	12.00	14
AG	0.621	1.071	172.4	4.10	0.00	14
SN	0.000	0.000	0.0	0.00	0.00	14
BA	186.071	53.238	28.6	248.00	94.00	14
LA	62.071	10.651	17.1	91.00	47.00	14
PB	9.357	6.209	66.3	25.00	2.00	14
BI	0.857	1.747	203.9	5.00	0.00	14
LI2	71.500	28.755	40.2	134.00	23.00	14
MN2	0.009	0.015	171.3	0.04	0.00	14
PB2	0.000	0.000	0.0	0.00	0.00	14
B1	608.428	70.188	11.5	770.00	531.00	14
B2	505.785	129.489	25.6	862.00	385.00	14
B3	435.000	117.758	27.0	771.00	330.00	14
K/RB	115.000	17.685	15.3	145.00	73.00	14

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RECALC. OMITTING SAMPLES OUTSIDE RANGE MEAN PLUS OR MINUS TWICE STD DEV
14 ORGANIC RICH SAMPLES


     ELEMENT         MEAN       STANDARD    COEFFICIENT OF    MAXIMUM      MINIMUM     NUMBER OF
                                DEVIATION     VARIATION        VALUE        VALUE    DETERMINATIONS

     IN            848.500       70.792           8.3         952.00       750.00          14
     EU            723.785       74.440          10.2         871.00       630.00          14
     RT            463.384       91.581          19.7         600.00       316.00          13
     LI             44.199       11.248          25.4          57.10        23.10          14
     BE              1.492        0.963          64.5           3.30         0.30          14
     B             166.000       68.955          41.5         250.00        68.00          14
     MGO             0.874        0.238          27.2           1.23         0.47          14
     AL2O3          12.485        4.881          39.0          19.80         3.90          14
     SIO2           34.278       12.800          37.3          51.40        12.70          14
     K2O             1.870        0.675          36.1           2.95         0.79          14
     CAO             7.978        2.022          25.3          10.16         3.38          13
     TIO2            0.793        0.196          24.7           1.03         0.45          13
     V             166.538       20.447          12.2         196.00       128.00          13
     CR             73.071       24.253          33.1         108.00        30.00          14
     MN            107.916       20.290          18.8         138.00        74.00          12
     FE2O3           4.932        1.386          28.1           7.12         2.28          14
     CO              8.307        2.868          34.5          14.00         3.00          13
     NI             65.461       12.339          18.9          86.00        49.00          13
     CU             46.642       12.200          26.1          70.00        25.00          14
     ZN            176.230       81.706          46.3         382.00        80.00          13
     GA             11.576        2.640          22.8          16.10         6.30          13
     GE              0.000        0.000           0.0           0.00         0.00          14
     RB            126.769       34.100          26.8         183.00        68.00          13
     SR            305.769       64.084          20.9         420.00       211.00          13
     Y              39.076        6.885          17.6          56.00        29.00          13
     ZR            102.000       34.681          34.0         171.00        47.00          13
     MO             47.615       53.668         112.7         198.00        12.00          13
     AG              0.353        0.397         112.2           1.00         0.00          13
     SN              0.000        0.000           0.0           0.00         0.00          14
     BA            186.071       53.238          28.6         248.00        94.00          14
     LA             59.846        6.914          11.5          71.00        47.00          13
     PB              8.153        4.450          54.5          20.00         2.00          13
     BI              0.538        1.330         247.0           4.00         0.00          13
     LI2            66.692       23.350          35.0         100.00        23.00          13
     MN2             0.009        0.015         171.3           0.04         0.00          14
     PB2             0.000        0.000           0.0           0.00         0.00          14
     B1            596.000       54.718           9.1         684.00       531.00          13
     B2            478.384       82.324          17.2         647.00       385.00          13
     B3            409.153       69.935          17.0         554.00       330.00          13
     K/RB          118.230       13.435          11.3         145.00       105.00          13
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13 ORGANIC DEFICIENT SAMPLES


     ELEMENT          MEAN        STANDARD   COEFFICIENT OF    MAXIMUM         MINIMUM      NUMBER OF
                                  DEVIATION     VARIATION       VALUE           VALUE   DETERMINATIONS

     IN              753.153       83.706          11.1         919.00          626.00          13
     FU              723.846       73.218          10.1         842.00          623.00          13
     RT              622.230       68.450          11.0         700.00          439.00          13
     LI               50.684        6.641          13.1          58.10           41.80          13
     BE                1.969        1.098          55.7           4.20            0.30          13
     B               208.076       40.413          19.4         266.00          112.00          13
     MGO               1.107        0.364          32.9           1.78            0.75          13
     AL2O3            15.546        2.290          14.7          19.30           11.30          13
     SIO2             59.338        9.992          16.8          70.40           34.30          13
     K2O               2.877        0.275           9.5           3.45            2.56          13
     CAO               4.004        3.230          80.6          10.64            0.49          13
     TIO2              0.886        0.094          10.7           1.04            0.72          13
     V                94.307       24.536          26.0         149.00           57.00          13
     CR               75.846       12.902          17.0          92.00           52.00          13
     MN              127.307       39.883          31.3         161.00            0.00          13
     FE2O3             4.357        0.866          17.8           6.99            3.86          13
     CO                7.846        1.863          23.7          11.00            5.00          13
     NI               31.461        7.229          22.9          46.00           19.00          13
     CU               26.846        4.219          15.7          34.00           20.00          13
     ZN               79.923       56.018          70.0         239.00           36.00          13
     GA               14.730        2.366          16.0          19.60            9.80          13
     GE                2.384        2.467         103.4           6.00            0.00          13
     RB              196.153       16.841           8.5         232.00          178.00          13
     SR              244.923       68.484          27.9         392.00          158.00          13
     Y                31.076        4.310          13.8          38.00           25.00          13
     ZR              273.923      127.606          46.5         454.00           74.00          13
     MO                4.692        6.128         130.6          23.00            0.00          13
     AG                0.161        0.475         294.2           1.70            0.00          13
     SN                1.000        1.732         173.2           4.00            0.00          13
     BA              280.923       43.282          15.4         334.00          178.00          13
     LA               52.076        8.519          16.3          69.00           39.00          13
     PB                5.153        3.362          65.2          11.00            0.00          13
     BI                1.692        2.250         132.9           5.00            0.00          13
     LI2              67.000       28.003          41.8         129.00           37.00          13
     MN2               0.006        0.015         244.0           0.04            0.00          13
     PB2              15.384       17.046         110.8          48.00            0.00          13
     R1              591.846       74.457          12.7         753.00          500.00          13
     R2              404.692       99.155          24.5         670.00          321.00          13
     R3              337.307       92.917          27.5         580.00          255.00          13
     K/RB            121.846       10.976           9.0         138.00           96.00          13
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RECALC. OMITTING SAMPLES OUTSIDE RANGE MEAN PLUS OR MINUS TWICE STD DEV
13 ORGANIC DEFICIENT SAMPLES



          ELEMENT         MEAN          STANDARD     COEFFICIENT OF     MAXIMUM          MINIMUM       NUMBER OF
                                        DEVIATION       VARIATION        VALUE            VALUE    DETERMINATIONS

          IN            753.153          83.706          11.1           919.00           626.00           13
          EU            723.846          73.218          10.1           842.00           623.00           13
          PT            637.500          42.485           6.6           700.00           550.00           12
          LI             50.684           6.641          13.1            58.10            41.80           13
          BE              1.783           0.908          50.9             3.50             0.30           12
          B             216.083          29.540          13.6           266.00           177.00           12
          MGO             1.107           0.364          32.9             1.78             0.75           13
          AL2O3          15.546           2.290          14.7            19.30            11.30           13
          SIO2           61.424           6.868          11.1            70.40            49.50           12
          K2O             2.829           0.224           7.9             3.28             2.56           12
          CAO             3.451           2.654          76.9             7.56             0.49           12
          TIO2            0.886           0.094          10.7             1.04             0.72           13
          V              89.750          19.031          21.2           133.00            57.00           12
          CR             75.846          12.902          17.0            92.00            52.00           13
          MN            137.916          11.797           8.5           161.00           119.00           12
          FE2O3           4.679           0.608          13.0             5.84             3.86           12
          CO              7.846           1.863          23.7            11.00             5.00           13
          NI             30.250           6.017          19.8            40.00            19.00           12
          CU             26.846           4.219          15.7            34.00            20.00           13
          ZN             66.666          30.514          45.7           143.00            36.00           12
          GA             14.736           1.385           9.3            16.80            12.50           11
          GE              2.384           2.467         103.4             6.00             0.00           13
          RB            193.166          13.523           7.0           225.00           178.00           12
          SR            232.666          54.644          23.4           329.00           158.00           12
          Y              31.076           4.310          13.8            38.00            25.00           13
          ZR            273.923         127.606          46.5           454.00            74.00           13
          MO              3.166           2.823          89.1             9.00             0.00           12
          AG              0.033           0.115         346.4             0.40             0.00           12
          SN              1.000           1.732         173.2             4.00             0.00           13
          BA            289.500          31.629          10.9           334.00           243.00           12
          LA             52.076           8.519          16.3            69.00            39.00           13
          PB              5.153           3.362          65.2            11.00             0.00           13
          BI              1.692           2.250         132.9             5.00             0.00           13
          LI2            61.833          21.845          35.3            95.00            37.00           12
          MN2             0.000           0.000           0.0             0.00             0.00           11
          PB2            15.384          17.046         110.8            48.00             0.00           13
          B1            567.583          56.240           9.9           664.00           500.00           12
          B2            382.583          61.591          16.0           480.00           321.00           12
          B3            317.083          60.147          18.9           405.00           255.00           12
          K/RB          124.000           8.101           6.5           138.00           113.00           12
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KIMMERIDGE OIL SHALES SAMPLE NUMBERS 102-111

ELEMENT	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MAXIMUM VALUE	MINIMUM VALUE	NUMBER OF DETERMINATIONS
IN	838.900	95.406	11.3	920.00	670.00	10
FU	703.500	64.101	9.1	804.00	582.00	10
PT	475.500	100.691	21.1	647.00	300.00	10
LI	50.899	6.293	12.3	56.40	36.90	10
BE	1.499	0.734	48.9	2.60	0.40	10
B	156.400	35.935	22.9	229.00	112.00	10
MGO	1.144	0.115	10.0	1.35	0.95	10
AL2O3	14.159	3.854	27.2	22.00	9.60	10
SIO2	39.079	7.258	18.5	51.50	31.80	10
K2O	2.150	0.384	17.8	2.65	1.66	10
CAO	9.396	2.576	27.4	13.16	6.63	10
TIO2	0.828	0.148	17.9	1.01	0.54	10
V	129.800	20.384	15.7	159.00	100.00	10
CR	72.800	12.363	16.9	91.00	52.00	10
MN	76.100	67.249	88.3	157.00	0.00	10
FE2O3	4.643	1.056	22.7	6.99	3.33	10
CO	7.200	1.686	23.4	10.00	5.00	10
NI	49.500	10.700	21.6	61.00	26.00	10
CU	35.100	5.486	15.6	43.00	26.00	10
ZN	152.900	41.354	27.0	239.00	110.00	10
GA	12.919	2.565	19.8	17.10	9.70	10
GE	0.100	0.316	316.2	1.00	0.00	10
RB	166.200	36.738	22.1	238.00	130.00	10
SR	314.200	38.906	12.3	358.00	240.00	10
Y	39.400	9.754	24.7	59.00	28.00	10
ZR	91.700	52.004	56.7	184.00	33.00	10
MO	13.100	8.020	61.2	25.00	3.00	10
AG	0.419	0.559	133.1	1.70	0.00	10
SN	0.000	0.000	0.0	0.00	0.00	10
BA	225.300	43.954	19.5	294.00	154.00	10
LA	64.300	12.987	20.1	82.00	46.00	10
PB	3.000	3.333	111.1	11.00	0.00	10
BI	0.000	0.000	0.0	0.00	0.00	10
LI2	87.300	20.656	23.6	129.00	58.00	10
MN2	0.014	0.018	131.2	0.04	0.00	10
PB2	0.000	0.000	0.0	0.00	0.00	10
B1	634.900	55.744	8.7	753.00	557.00	10
B2	510.500	83.173	16.2	670.00	411.00	10
B3	441.200	76.166	17.2	580.00	339.00	10
K/RB	108.600	11.403	10.5	129.00	85.00	10

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RECALC. OMITTING SAMPLES OUTSIDE RANGE MEAN PLUS OR MINUS TWICE STD DEV
KIMMERIDGE OIL SHALES SAMPLE NUMBERS 102-111


     ELEMENT        MEAN        STANDARD     COEFFICIENT OF    MAXIMUM      MINIMUM      NUMBER OF
                                DEVIATION       VARIATION       VALUE        VALUE     DETERMINATIONS

     IN           838.900        95.406           11.3         920.00       670.00          10
     EU           703.500        64.101            9.1         804.00       582.00          10
     RT           475.500       100.691           21.1         647.00       300.00          10
     LI            52.455         4.164            7.9          56.40        43.30           9
     BE             1.499         0.734           48.9           2.60         0.40          10
     B            148.333        26.846           18.0         193.00       112.00           9
     MGO            1.144         0.115           10.0           1.35         0.95          10
     AL203         13.288         2.859           21.5          19.30         9.60           9
     SIO2          39.079         7.258           18.5          51.50        31.80          10
     K2O            2.150         0.384           17.8           2.65         1.66          10
     CAO            9.396         2.576           27.4          13.16         6.63          10
     TIO2           0.828         0.148           17.9           1.01         0.54          10
     V            129.800        20.384           15.7         159.00       100.00          10
     CR            72.800        12.363           16.9          91.00        52.00          10
     MN            76.100        67.249           88.3         157.00         0.00          10
     FE203          4.383         0.701           15.9           5.60         3.33           9
     CO             7.200         1.686           23.4          10.00         5.00          10
     NI            52.111         7.218           13.8          61.00        41.00           9
     CU            35.100         5.486           15.6          43.00        26.00          10
     ZN           143.222        29.865           20.8         200.00       110.00           9
     GA            12.919         2.565           19.8          17.10         9.70          10
     GE             0.000         0.000            0.0           0.00         0.00           9
     RB           166.200        36.738           22.1         238.00       130.00          10
     SR           314.200        38.906           12.3         358.00       240.00          10
     Y             37.222         7.327           19.6          54.00        28.00           9
     ZR            91.700        52.004           56.7         184.00        33.00          10
     MO            13.100         8.020           61.2          25.00         3.00          10
     AG             0.277         0.352          126.9           1.00         0.00           9
     SN             0.000         0.000            0.0           0.00         0.00          10
     BA           225.300        43.954           19.5         294.00       154.00          10
     LA            64.300        12.987           20.1          82.00        46.00          10
     PB             2.111         1.900           90.0           6.00         0.00           9
     BI             0.000         0.000            0.0           0.00         0.00          10
     LI2           82.666        15.443           18.6         107.00        58.00           9
     MN2            0.014         0.018          131.2           0.04         0.00          10
     PB2            0.000         0.000            0.0           0.00         0.00          10
     B1           621.777        39.480            6.3         670.00       557.00           9
     R2           510.500        83.173           16.2         670.00       411.00          10
     R3           441.200        76.166           17.2         580.00       339.00          10
     K/RB         111.222         8.303            7.4         129.00       100.00           9
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Appendix B:
Possible structural clay product applications of oil shale and oil shale/mudstone mixtures from the Kimmeridge Clay

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Appendix B:
Possible structural clay product applications of oil shale and oil shale/mudstone mixtures from the Kimmeridge Clay

INTRODUCTION

In order to supplement the information on the regional variations in the composition of oil shales and oil shale/mudstone mixtures in the Kimmeridge Clay, six selected samples from three boreholes were investigated. Their mineralogical nature was examined in conjunction with an assessment of such physico-chemical properties as might be useful in evaluating their potential as mineral raw materials for use in the manufacture of structural clay products.

The six samples were identified as follows:

Borehole	Sample depth (m)	Sample no. (KOS)	Lab. no.
North Runcton	23.00 - 24.00	839	2202 A
North Runcton	25.00 - 26.00	840	2202 B
Donington on Bain	43.05 - 44.05	841	2202 C
Donington on Bain	45.05 - 46.05	842	2202 D
Portesham	51.25 - 52.25	843	2202 E
Portesham	53.24 - 54.24	844	2202 F

In the following report the samples are referred to by their suffix letters (A to F).

MINERALOGY

Preliminary X-ray diffraction (XRD) examination of 'randomly-oriented' mounts of the ground samples showed that all contained quartz, calcite, pyrite and gypsum, together with variable amounts of clay minerals. The nature of the clay mineral assemblage was determined by XRD examination of 'basally-oriented' mounts of the dispersed samples, using ancillary glycerolation and heating tests where required. Diffraction traces of the air-dried samples are shown in Fig. B1. Samples A, B and C contained an identical assemblage of kaolinite, mica, montmorillonite, a 12 Å phase tentatively identified as mixed-layer illite-montmorillonite and, possibly, chlorite in trace amounts. Relative proportions of these minerals were very similar in all three samples and only the diffraction trace of sample B is figured. Kaolinite, mica, montmorillonite and ?chlorite were also identified in sample D, although the 12 Å phase appeared to be lacking. Total clay minerals were much higher than in the previous three samples, however. Sample E contained only kaolinite and

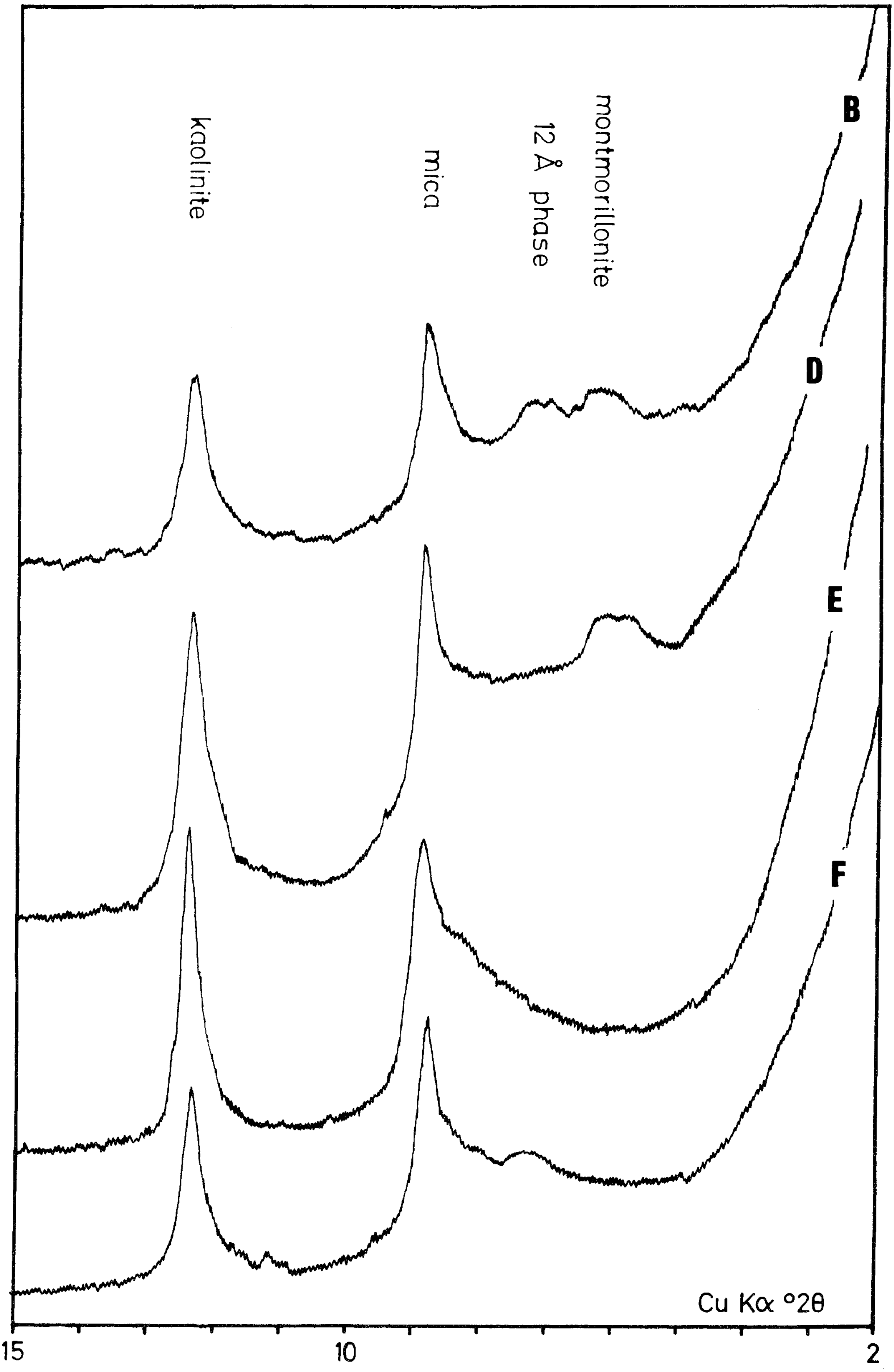


Figure B1 X-ray diffraction traces of clay fractions from samples B, D, E and F mica, the marked asymmetry of the mica peak towards lower 2θ angles suggesting that it was an intergrade variety. Both XRD results and K_2O values (Table B1) indicated that this sample contained the highest amount of mica. Sample F contained kaolinite, mica and the 12 Å phase and had a total clay mineral content comparable to samples A, B and C.

The samples were known to contain substantial amounts of (kerogen-rich) organic matter and data on its thermal degradation behaviour and, inter alia, relative amounts present in the samples were obtained using a simultaneous differential thermal analysis (DTA) - evolved gas analysis (EGA) technique. This involved heating the sample in a conventional DTA furnace from room temperature to 1000° C at a rate of 10° C/min while a 2:1 mixture by volume of N_2 and O_2 passed through the furnace at a constant rate of 300 ml/min. Volatiles evolved from the sample during the heating programme were transported by the N_2/O_2 mixture to three gas detectors arranged in series which monitored, respectively, concentrations of H_2O, CO_2 and SO_2 in the carrier gas as a function of temperature. Outputs from these detectors were fed into a multichannel chart recorder which also displayed the DTA signal. Weights of any of the three volatiles released during a particular temperature interval were obtained by a simple calculation following measurement of peak area on the respective evolution profile. As well as monitoring volatile release from the organic matter on combustion, this technique also provided information on the dehydroxylation characteristics of the clay minerals present, the temperature range during which oxidation of the pyrite occurred, and the calcite contents of the samples (from the amount of CO_2 evolved during dissociation of this mineral between 700-800° C).

Figs. B2a-c show simultaneous DTA-EGA curves of sample C (which proved to contain the highest amount of organic matter) obtained under different experimental conditions. In Fig. B2a, the DTA curve ($\triangle$ T) exhibits a small initial endothermic depression, a large broad exotherm extending from 150° C to 700° C and, following almost immediately, an endotherm with a peak at 780° C. The large exotherm results from combustion of the organic matter in the oxidizing environment provided by the N_2/O_2 carrier gas, the rather large temperature range over which the reaction occurs being a function of the rate of diffusion of the gas into the sample, which in this run was packed firmly into the DTA crucible. The limits of the large CO_2 evolution peak coincide exactly with those of the large DTA exotherm. The subsidiary peak on the CO_2 evolution profile is due to CO_2 released during the dissociation of calcite and coincides with the DTA endotherm peaking at 780° C. Amounts of CO_2 resulting from oxidation of organic matter and dissociation of calcite were determined and from these values equivalent organic C and calcite contents were obtained for each sample (Table B2). The H_2O evolution profile also shows three peaks. The first (130°C) is due to loss of adsorbed moisture, the second (320° C) is connected with

Table B1 Partial chemical analyses obtained by X-ray fluorescence examination of elvasite-bound discs. Analyst: D. J. Bland

	A	B	C	D	E	F
% Fe_2O_3	5.38	5.59	6.30	7.21	7.50	5.91
% MgO	1.42	1.28	1.28	1.50	1.25	1.18
% CaO	12.0	16.7	12.8	8.2	2.9	11.3
% Na_2O	0.39	0.36	0.51	0.56	0.84	0.72
% K_2O	2.56	2.18	2.34	2.81	3.47	2.72

Table B2 Figures derived from evolved gas analysis (details in text)

	A	B	C	D	E	F
CO_2 generated during combustion or organic matter (% of original sample)	50.5	44.4	56.5	24.1	19.7	36.8
equivalent organic C (%)	13.6	12.1	15.4	6.6	5.4	10.0
CO_2 generated during dissociation of calcite (% of original sample)	4.6	6.4	5.7	3.0	1.2	5.0
equivalent calcite (%)	10.5	14.5	12.8	6.8	2.8	11.3

the oxidative breakdown of the organic matter, and the third (550° C) represents dehydroxylation of the clay minerals present. Most of the SO_2 evolved resulted from oxidation of pyrite but the initial shoulder on the evolution profile of this volatile suggests that some SO_2 may have been generated by oxidation of S contained in the organic fraction. This is confirmed in Fig. B2b which represents an EGA run carried out under slightly different conditions. No DTA curve was recorded as the sample was spread thinly over the base of a shallow crucible placed on top of the DTA measuring head. It is apparent from the sharpness of the EGA peaks that most of the reactions connected with combustion of the organic matter

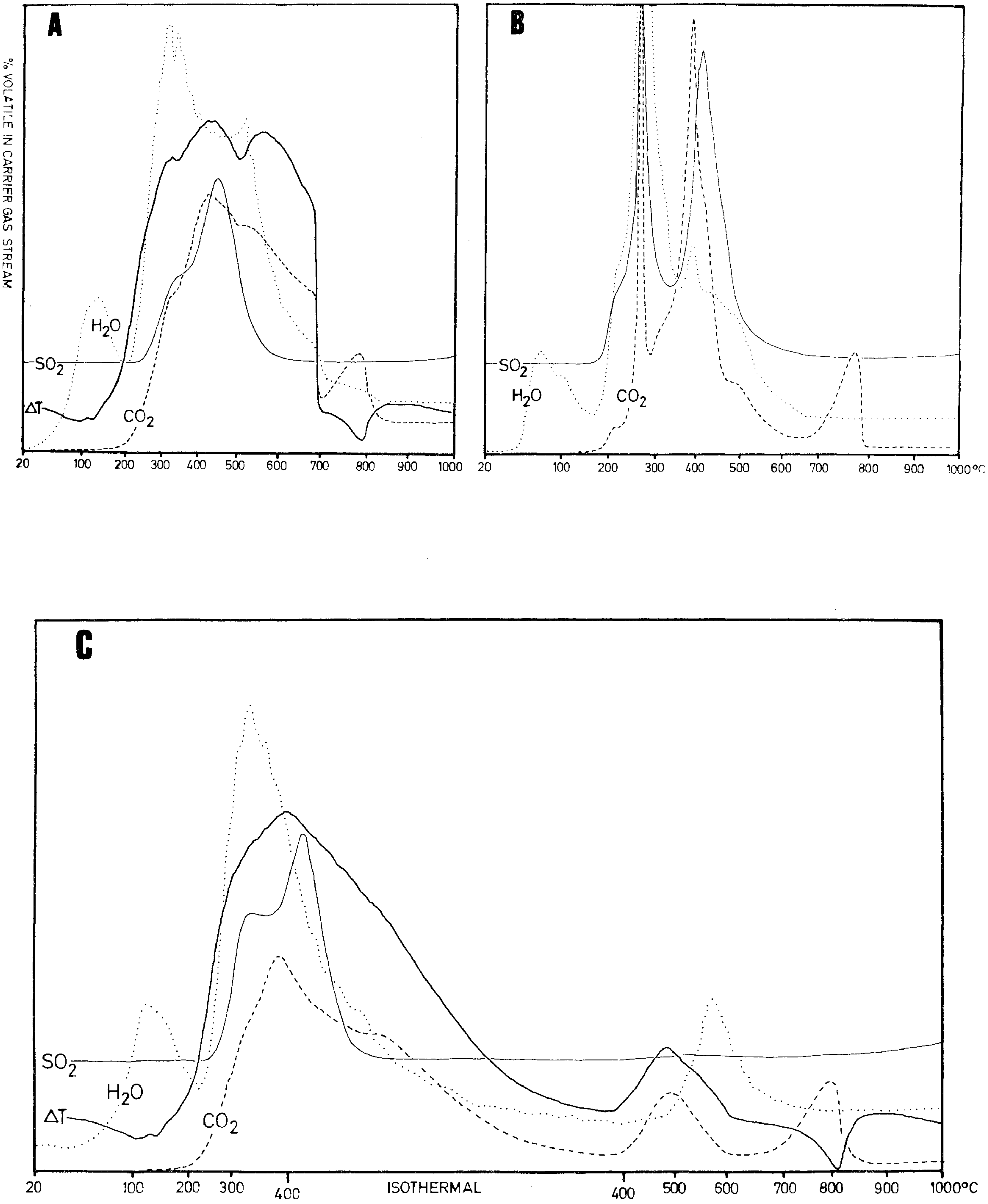


Figure B2 Differential thermal analysis – evolved gas analysis (DTA-EGA) of sample C proceeded much quicker than in the previous run due to the increased contact of the sample with the oxidizing environment. Oxidation appeared to occur in two stages with CO_2 peaks at 260° C and 420° C. Combustion of the more volatile component was accompanied by simultaneous release of H_2O and SO_2. Peaks due to organic matter-generated SO_2 and oxidation of pyrite were well resolved under these conditions.

Fig. B2c shows the results of a further DTA-EGA run which was carried out to determine whether, by using isothermal conditions, complete oxidation of the organic matter could be accomplished before dehydroxylation of the clay minerals occurred. Conditions were identical to those used to produce Fig. B2a except that the heating programme was stopped at 400° C and reactions allowed to continue at this temperature. It can be seen from the figure that holding at 400° C for 30 mins resulted in almost complete breakdown of the organic matter. A small oxidation exotherm on the DTA curve and a corresponding peak on the CO_2 evolution profile occurred soon after the heating programme was re-started, these signifying combustion of the remaining organic matter. Dehydroxylation of the clay minerals is clearly represented by the peak on the H_2O evolution profile between 500° C and 650° C.

TECHNICAL TESTING

The limited size of the samples (small portions of the core) precluded large-scale testing of the clays but some basic data were sought on specific properties of an applied nature. The mixed-assemblage character of the samples would confine potential uses of the clay largely to those of a bulk material allied to the manufacture of structural ceramics or products for the building industries. Here, the effects of clay identity and relative changes in overall clay composition on both clay-water consistency and behaviour on firing are important evaluation parameters. However, of equal consequence in this case are the high contents of carbonaceous matter (as an integral fuel in the firing of ware) and the volatiles evolved from the organic compounds, the calcite (CO_2) and the pyrite (SO_2).

CLAY-WATER RELATIONSHIPS

The plastic behaviour of a clay when tempered with water is an inherent property utilised in forming or shaping ware prior to firing. Its basic nature may be assessed by determining Atterberg Limits for the samples – a Plastic Limit (the minimum % water required to roll the clay into thin 1/8" diam. rods without crumbling) and a Liquid Limit (the water content of a thick clay slurry when just sufficiently liquid to flow when jarred in a Casagrande apparatus). The arithmetical difference between these limiting values gives the "plasticity index". The figures determined for the six Kimmeridge clays are shown in Table B3.

The plasticity indices, mostly in the range 20-25, are very moderate for clay-rich

Table B3 Wetting and Drying Behaviour

	A	B	C	D	E	F
Liquid Limit (%wt)	67	61	60	65	47	54
Plastic Limit (%wt)	43	37	40	35	29	33
Plasticity Index	24	24	20	20	18	21
Solids volume (ml/100g)	47.8	46.5	49.2	43.3	41.6	45.6
Pore space (ml/100g)	22.1	18.8	20.1	15.7	15.3	18.3
Drying shrinkage (% vol)	23.0	21.8	22.3	24.7	19.4	18.7

material but at about the consistency level most suited for plastic shaping of clay ware (hand-working, extrusion, etc.). Inter-particle association at this consistency should also ensure sufficiently good bonding properties for the ware to be handled safely without disintegrating or falling apart through lack of strength.

This is shown diagrammatically in Fig. B3a where an inner (optimum) and outer (acceptable) range of values for plasticity index and plastic limit are delineated by rectangles circumscribed by double and single lines respectively. The present samples have been displaced towards the top of the diagram (Fig. B3b) under the influence of moderately-high plastic limit values. This has an important effect on the subsequent shrinkage of the plastic body on drying – see the shrinkage scale at the right of the diagram. The more water required by the clay to reach its plastic state (the higher the plastic limit) the more must be removed on drying and hence the greater the shrinkage suffered. These samples would be expected to undergo moderately-high to very-high shrinkages on drying from the plastic consistency.

The high water absorbency of the Kimmeridge Clay samples is partly accounted for by the organic matter component which acts with a sponge-like capacity in holding water. It will be noted that the samples A and C contain the most, and sample E the least, amounts of carbonaceous material.

In practice, the actual shrinkage suffered by a plastic clay body on drying also depends on the volumetric relationship between solids and pore space in the dry state. Values for these parameters were measured in the course of the Atterberg Limit determinations (after oven-drying at 105° C) and are recorded in Table B3. A simple calculation provided the values for volumetric shrinkage shown at the bottom of the table. The figures, ranging from 18.7% to 24.7% are, indeed, moderately high to high. Linear drying shrinkages, which are rather easier to visualise in assessing building products, would be roughly a third of the volumetric figures.

FIG. B3 (a)

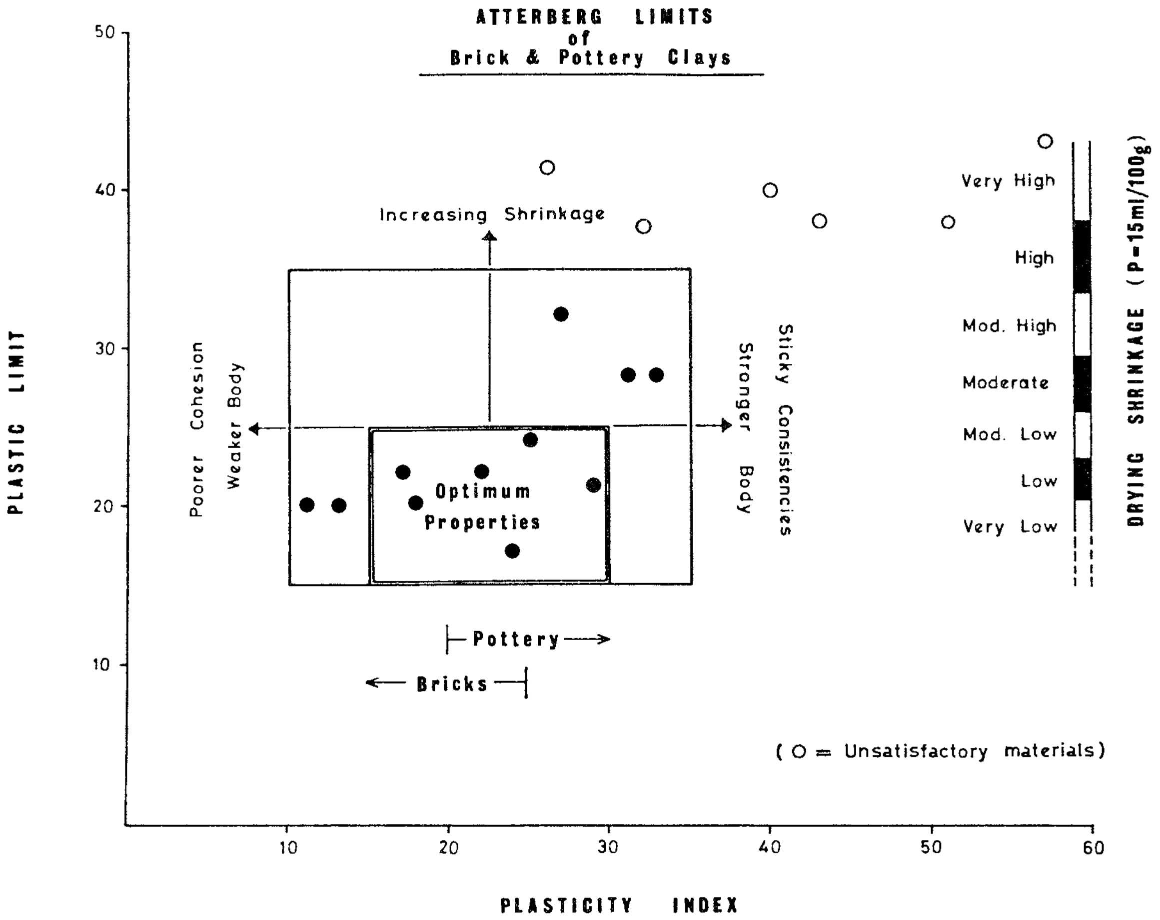


FIG. B3 (b)

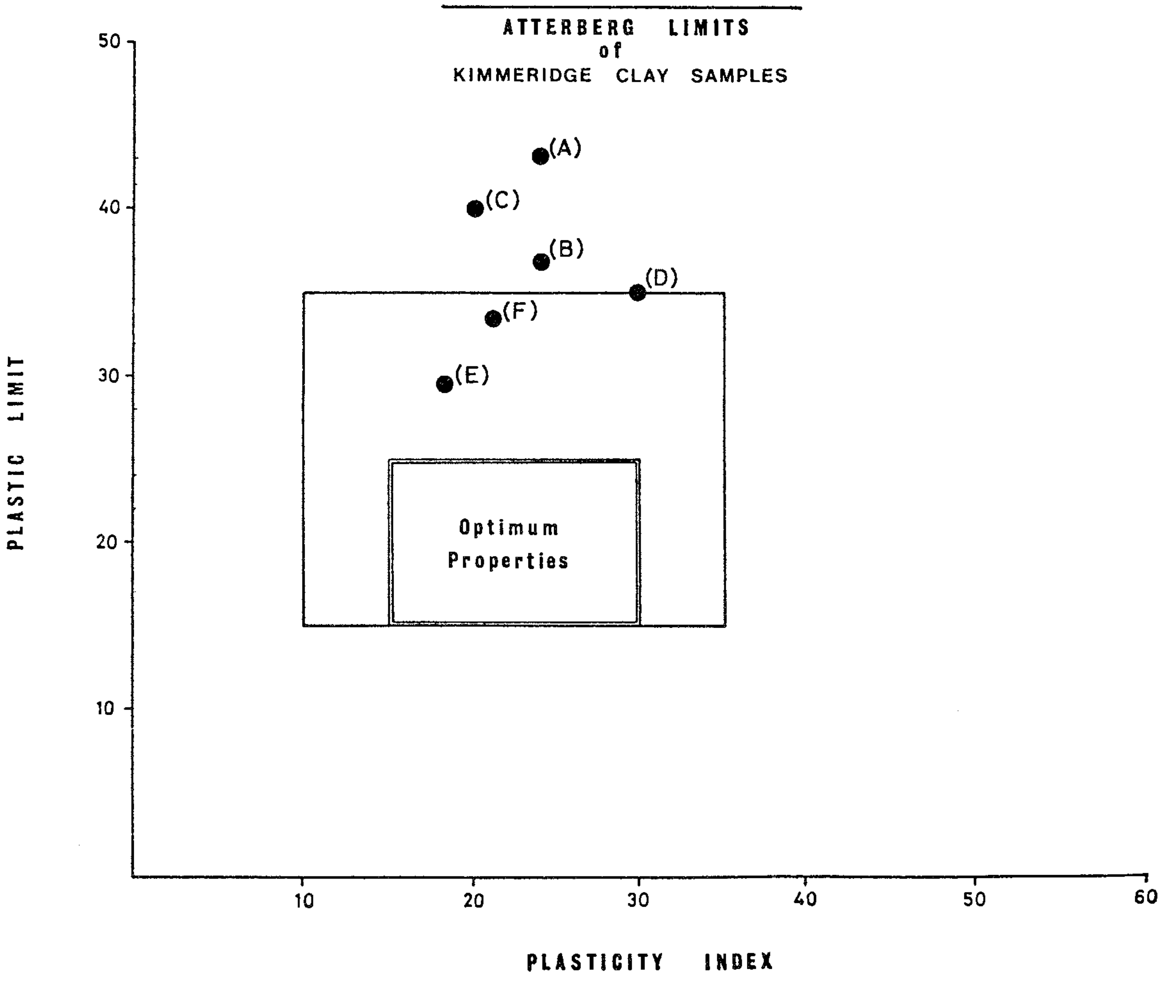


Table B4 Data from Single Firing Trials

	A	B	C	D	E	F
a. Firing at 1050° C						
Ignition loss (wt%)	31.3	29.1	31.1	20.0	15.0	23.3
Body porosity (vol %)	55.7	54.0	55.9	29.5	18.3	48.2
Fired colour	Greyish-buff	Creamy-buff	Greyish-buff	Pale-Brown	Medium-Brown	Pale-Brown
b. Cone squatting test						
softening or melting pt. (° C)	1215	1180	1220	1340	1250	1260

These clay samples, therefore, would appear to be eminently suitable for forming ware in the plastic state but would exhibit moderately high to high shrinkage on drying – the magnitude of this effect being partly a function of the organic matter content.

FIRING BEHAVIOUR

Properties on heating

As an introductory heating experiment, a single small piece of the plastic clay body, after oven-drying, was heated to the standard "ignition" temperature of 1050° C to determine weight loss, body porosity and fired colour. In addition, a shaped cone of clay was heated to its collapsed or squatting temperature to determine its softening or melting point (pyrometric cone equivalent). The results of these tests for each of the Kimmeridge Clay samples are recorded in Table B4.

The very high ignition losses noted for samples A-C are a measure of the combined losses for carbonaceous matter, carbon dioxide from calcite, some sulphur dioxide from pyrite and a little hydroxyl water from clay constituents. Such large losses would inevitably have a pronounced effect on the firing behaviour and properties of ceramic products. Sample F exhibits a somewhat lower weight loss on firing. Samples D and E are lower still (the latter containing very little carbonate) but show a relatively greater contribution from hydroxyl water losses associated with higher clay contents.

The fired pieces are fairly strong, yielding a distinct resonant "ring" when struck; fired colour ranges from a greyish-buff for samples A-C to a medium brown for samples D-F.

An important feature of these test results is the very high porosities displayed by the fired test pieces, particularly in the case of samples A-C (more than 50% by volume) and, to a lesser extent, by sample F. Even sample D exhibits moderately-high porosity. This is a consequence of the burning-off of organic matter and, to a more marked degree, the loss of

CO_2 from the dissociation of calcite. Water absorption properties of structural ceramics (bricks, tiles, etc.) made from these clays are thus likely to be high unless high firing temperatures are used to induce vitrification and the gradual elimination of pore space – a process which invariably produces high shrinkage as well.

The softening and melting termperatures recorded in Table B4 are, with the exception of sample D, in the range 1180° C-1260° C. These are quite low figures for clays and indicate pronounced fluxing properties so that the samples would be expected to show good vitrification characteristics on kiln firing at the temperatures usually employed for the preparation of structural clay products. This behaviour can be related to the presence of alkalies, alkaline earths and iron (in the ferrous state) – fluxing constituents which are present in major amounts in the Kimmeridge Clay samples. The clay species mica/illite and montmorillonite are particularly effective in this respect.

Vitrification characteristics

The vitrification behaviour of clays is most easily evaluated by monitoring the progressive elimination of pore space in test pieces fired at successively higher temperatures. Standard rod-shaped test pieces were prepared from the Kimmeridge Clay samples by plastic extrusion through a $\frac{1}{2}''$ diam. die and subsequently cutting the continuous column into 2" lengths. These were used for firing at 50° C intervals from 950° C upwards, the cooled pieces being used for mercury and water displacement measurements to determine porosity and shrinkage.

The porosity changes recorded with rise in temperature are shown in diagrammatic form in the six charts comprising Fig. B4. Samples A-C show very similar firing behaviour. The graphs illustrate the initial large increase in pore space brought about by elimination of organic matter and carbon dioxide from the carbonate constituent, porosity values increasing from about 30% by volume in the unfired (oven-dried) condition to 53-56% by volume at 950° C. This state persists to about 1100° C but is followed by very rapid vitrification and the virtual collapse of body structure. Very dense, strong fired ware is produced but, in practice, the firing range is so short that the operation of a kiln would almost be impossible to control with any degree of consistency. In addition, the overall firing shrinkage recorded for test pieces removed at 1150° C was found to be in the range 44-52% by volume (equivalent to about 17-21% linear shrinkage) – excessively high.

Sample F shows similar but somewhat less pronounced behaviour, with a body porosity of about 47% by volume persisting from 950° C to 1100° C and followed by rapid vitrification. A firing shrinkage of 38% by volume was recorded at 1150° C. The same trend is exhibited by sample D but the removal of smaller amounts of organic matter and CO_2 from calcite produced a less open texture (about 41% porosity by volume between 950° C and 1100° C) and

FIG. B4 FIRING BEHAVIOUR

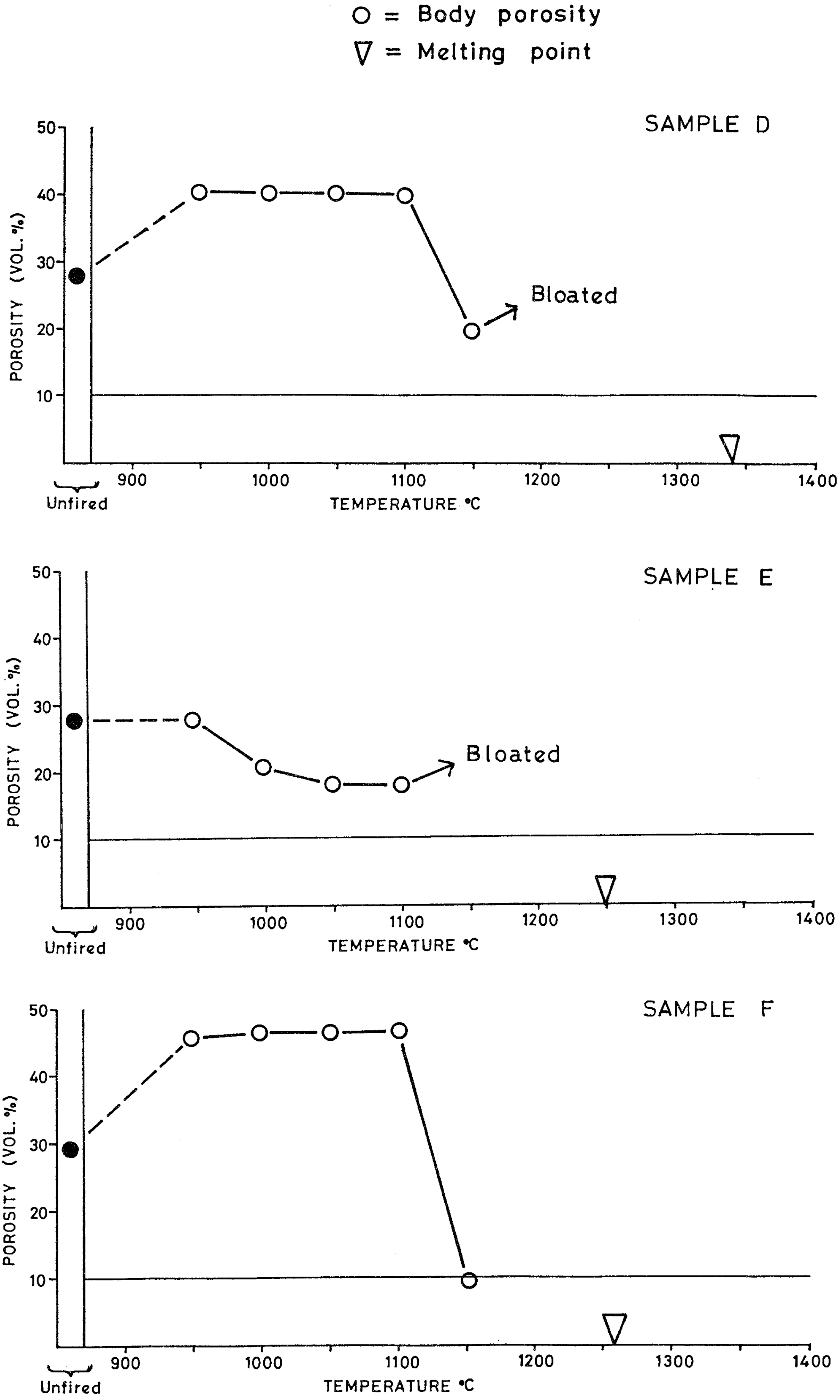
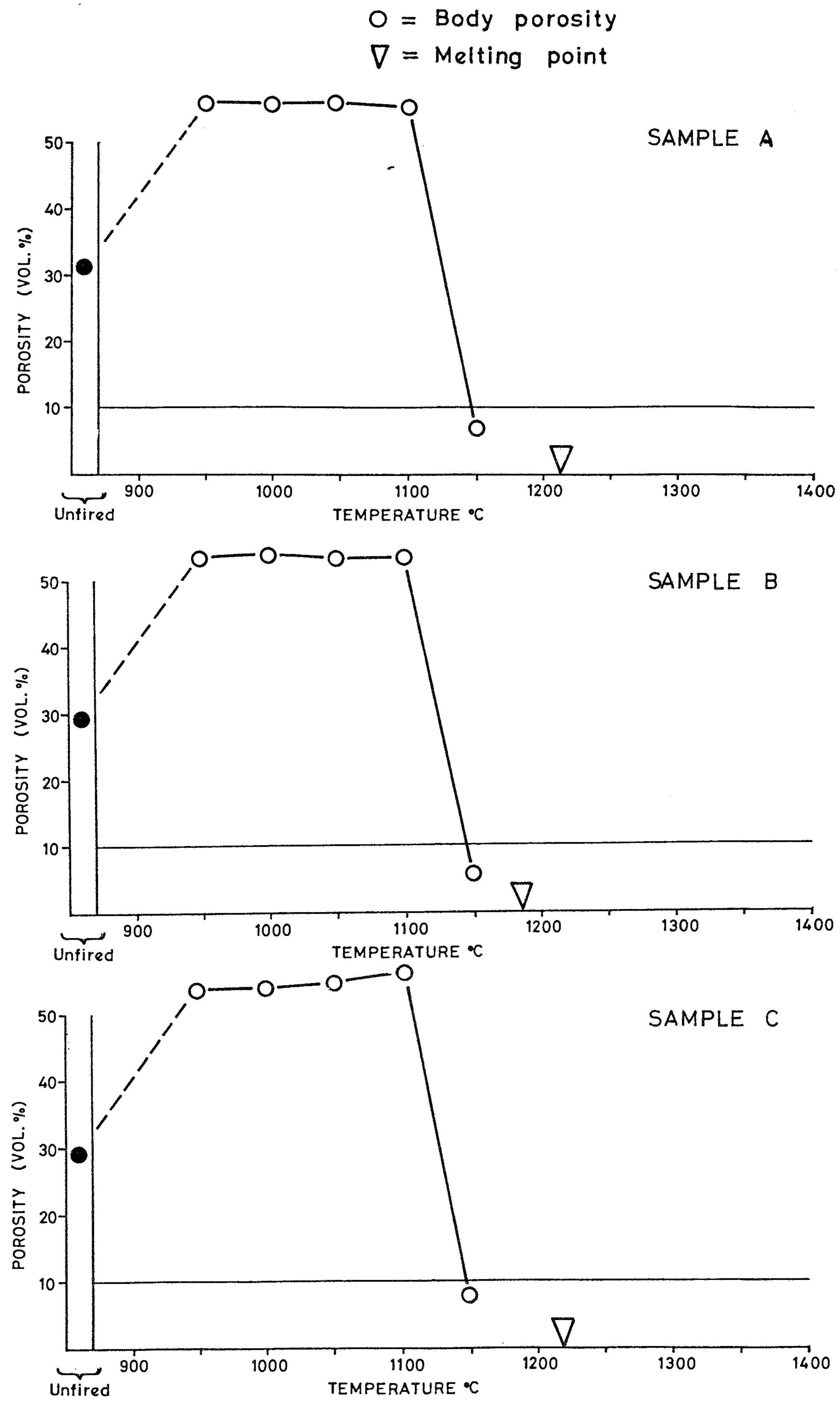


FIG. B4 contd.

FIRING BEHAVIOUR



bloating occurs before vitrification is well underway.

Sample E produced much more favourable firing characteristics with little change in body texture until the onset of gradual vitrification at 1000° C–1050° C. This produced a strong fired test piece but retaining a porosity of about 20% by volume. Overfiring induced bloating.

The more bituminous beds of the Kimmeridge Clay examined here exhibit a marked propensity for high shrinkage, both in drying from the plastic state and in firing to produce ceramic ware. In the latter case, high body porosities and the rapid onset of vitrification and deformation are characteristics which would be viewed unfavourably in their assessment as raw material for structural ceramics.

The presence of sufficient organic matter to act as fuel in firing ware would be a considerable advantage in the economics of kiln operation, especially as combustion would take place at lower temperatures where it was most needed. However, it would seem necessary to consider the use of dry or semi-dry pressing in forming ware in order to reduce porosity and shrinkage – as is, indeed, done in the making of fletton bricks from the carbonaceous beds of the Oxford Clay. It should be noted that the amount of organic matter present in some cases is notably high and the danger of actually igniting the combustible material in the kiln should not be overlooked.

The presence of a considerable volatile component and the ready fluxing nature of the clay suggests that the preparation of a "bloated clay" product for use as a lightweight aggregate or for various insulating purposes might be an alternative use for the Kimmeridge Clay samples examined here. High-temperature bloating was noted in at least two cases of over-firing.

Small pellets formed from the plastic clay, which were oven-dried and rapidly fired at 1150° C, did, indeed, produce a markedly bloated product but this was more of a "frothed" nature than the product of a controlled gaseous expansion contained within a viscous skin. The necessary rapid-firing procedure also led to the production of considerable volumes of acrid smoke from the bituminous constituent and further experiments on the raw shale were abandoned.

INVESTIGATION OF THE PROPERTIES OF "SPENT SHALE"

Some of the problems to be faced in the utilisation of Kimmeridge oil shale as a mineral raw material have been outlined above and an attempt has been made to relate physical properties and behaviour to composition – in this case a very mixed-assemblage one. It is suggested that the scope for potential uses might be enhanced if the bituminous constituent were removed; in other words, that attention should be directed towards a "spent shale" byproduct from which the oil had already been removed by distillation.

In this case, particularly if the retorting temperature approached the dehydroxylation temperature of the clay, the raw material might have lost its plasticity but the preparation of structural clay products either by dry pressing, or semi-plastic moulding after blending with some untreated clay, might be worthy of further investigation. At the same time, the evaluation of potential bloating behaviour, provided sufficient volatiles remained in the treated clay, could also be justified.

In addition, the potential pozzolanic (cementitious) behaviour of a "burnt clay" product when mixed with lime deserves durther investigation. This property arises from the very surface-reactive condition of the "amorphous" alumino-silicate phase remaining when a clay structure is destroyed on evolution of combined water. Although the normal retorting temperature for oil distillation might not be high enough to reach the dehydroxylation temperature of the clay component, the thermal analysis examination of the Kimmeridge Clay samples (see Fig. B2) demonstrated that this takes place at 550° C–650° C and that it would appear to be virtually complete at this temperature for all the clay species involved.

Practical trials are required to assess whether the most active state appears immediately after dehydroxylation and the magnitude of the cementitious reaction with lime. Also, whether higher temperatures enhance the property and, if so, whether this would introduce complicating factors in the formation of an integral lime compound from the calcite already present in the clay (decomposition temperature about 700° C–850° C).

Further samples of Kimmeridge Clay, in somewhat larger quantities than were previously available, have been obtained for testing as a spent shale product.

Appendix: C:
X-ray diffraction analyses of oil shale and oil shale/mudstone mixtures from the Kimmeridge Clay

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Appendix: C:
X-ray diffraction analyses of oil shale and oil shale/mudstone mixtures from the Kimmeridge Clay

INTRODUCTION

Separated clay fractions (< 2 μm) of 155 samples of Kimmeridge Clay were analysed by XRD to determine their mineralogical composition. Additional analyses were made on 20 of the samples to determine the non-clay minerals. The results of the clay mineral analyses are summarized in Table C1 and in the diffractograms in Appendix I. The non-clay mineral results are summarized in Table 12. In addition to these results, analyses of selected Kimmeridge Clay samples from Norfolk have been published by Merriman (in Gallois, 1978, App. A) and from the oil shale pilot study boreholes in Norfolk and Lincolnshire by Merriman and Strong (in Gallois, 1979, App. B). The Kimmeridge Clay mudstones and oil shales are composed almost entirely of quartz, calcite, kerogen and clay minerals. Accessary minerals account for less than 5 per cent of the total rock (except where indicated as greater in Table 12).

NON-CLAY MINERALS

Fragments of dried mudstone from each of 20 samples were ground to pass 120-mesh seive and the resulting powders were packed into aluminium sample holders. Analysis was carried out on a Philips diffractometer using Ni-filtered Cukα radiation. The region 3° to 40° 2θ was scanned at $\frac{1}{2}$° 2θ per minute with generator settings 30 mA, 40 kv and diffractometer slits of 1°, 0.1 and 1°.

The most abundant non-clay minerals are quartz and calcite: their concentrations are expressed in Table 12 as a percentage of the total sample. These percentages were obtained by comparing the intensities of the characteristic quartz and calcite peaks with those obtained from artificial mixtures of quartz/montmorillonite and calcite/London Clay of known composition. Where calcite forms less than 1% of the sample, the amount is indicated as "just detectable". A second carbonate, ankerite or dolomite, occurs in some samples but usually forms no more than a few per cent of the total. Ankerite is, however, the dominant carbonate in one sample (KOS 851) where it forms 10-15% of the total. A few per cent of pyrite is present in all the samples examined. Feldspar is commonly present in amounts of less than 1%, but is considerably more abundant in samples KOS 847, 853, 854. Both gypsum and natrojarosite are secondary sulphates resulting from the breakdown of pyrite and probably crystallised whilst the cores were drying out.

CLAY MINERALS

The samples were hand-ground and approximately 2 g of each were decalcified in an ultrasonic bath with 1 N acetic acid (buffered at pH3 with sodium acetate). When effervescence had stopped, the samples were centrifugally washed with distilled water and dispersed in 0.1 N sodium hexametaphosphate solution by ultrasonic treatment and shaking. After an appropriate settling time (calculated from Stokes' Law) 5 ml samples of the less than 2 m e. s. d. fraction was collected in a pipette: these were flocculated with concentrated calcium chloride solution, and were centrifugally compacted. Two smears of the compacted clay were made on glass slides: the slides were dried at room temperature, and the resulting oriented aggregates were used for X-ray analysis.

The X-ray diffraction analyses were made with a Philips diffractometer using Ni-filtered Cu$k\alpha$ radiation. Generator settings were 20 mA and 30 kv; diffractometer slits were $\frac{1}{2}^\circ$ and 1° (receiving), rate of rotation was 1° 20 per minute, chart rate 40 x 2θ mm/h; time constant, 2 s; counting rate, 200 counts/s. An automatic sample changer was used. Four runs were made for each sample from 2° to 30° 2θ before and after various thermal and chemical treatments. One smear slide was examined untreated, and again after heating at 440° C for 2h. The other slide was examined after being heated over glycerol in an enclosed vessel for 2h at 110° C, and then again after heating to 550° C for 2h.

Analysis of the four diffractograms from each sample allowed the basal spacings (001) of the different groups of clay minerals to be identified. Identification was generally at group level only. Quantitative analyses were made using a modified version of the method published by Griffin (in Carver, 1971). In the present work the 440° C trace was used instead of the 180° C trace recommended by Griffin because it was found that partial rehydration took place at 180° C before the X-ray analyses could be completed. This method of quantification allows the proportions of kandite, chlorite, clay mica and 'expansible' minerals to be estimated: the proportions are expressed as percentages of the $< 2\,\mu$m fraction.

In the Kimmeridge Clay samples the heating behaviour of the kandite mineral suggests that it is kaolinite: some samples showed varying resistance to 550° C heating and may indicate the presence of small amounts of well-ordered kaolinite. With Griffin's method quantitative assessment of chlorite depends on the recognition of its 3.54 Å (004) peak. This peak could not be differentiated from the 3.59 Å (002) peak of kaolinite in any of the present samples. Where chlorite is present, the intensity of its 001 peak relative to the 001 peaks of mica and kaolinite suggests that it occurs as an accessory mineral (< 5%). Consequently, the kaolinite + chlorite values reported from the samples are effectively the kaolinite contents. The 'expansible' minerals calculated by Griffin's method may include smectite, vermiculite, and irregular mixed layer smectite/clay mica, vermiculite/smectite and vermiculite/clay mica. The 'expansible' mineral content of the samples has been allocated to various of these phases by visual inspection of the traces.

Qualitatively the clay assemblages of most of the Kimmeridge Clay samples consist of mixtures of clay mica, kaolinite, vermiculite, vermiculite/smectite, vermiculite/clay mica and smectite/clay mica, commonly with accessory chlorite. Discrete smectite is restricted to a few samples. The diffractograms from one hundred and fifty five samples are shown in Appendix I and the quantitative results are summarized in Table C1; these illustrate the mineralogical variations which occur within the clay assemblages of the samples of Kimmeridge Clay analysed in this project.

REFERENCE

CARVER, R.E. 1971. Procedures in sedimentary petrology. (New York: Wiley Interscience.) 653 pp.

Table C1 Quantitative results of XRD analyses of clay minerals.

Notes: (i) 'expansible' minerals includes all forms that either expand with glycerol saturation or collapse on heating to 440° C.
(ii) chlorite (which may comprise up to 5% of the total clay minerals) is included with kaolinite in the quantitative analyses.

Abbreviations:
s = smectite present in irregular mixed-layer clay minerals
v = vermiculite
\+ = present
\- = not detected
** = residual 7 Å peak from kaolinite on 550° C trace
s* = discrete smectite
v/m = irregularly interlayed vermiculite/mica
++ = present, relatively abundant
? = possibly present
† = poor trace, quantitative results uncertain

Borehole and depth (m)	Sample no. (KOS)	Kaolinite %	Clay mica %	Expansible minerals		Chlorite	Chlorite/mica
				Total %	Type		
Setchey excavation: Trench B	801	19	61	20	v, v/m	-	+
Clavell's Hard: Blackstone	802	25	56	19	s, v/m ?	+	?
N. Runcton B: 46.48	803	25	46	29	v, v/m	-	+
N. Runcton B: 48.37	804	16	43	41	s, v ?, v/m	+	+
N. Runcton B: 48.96	805	15	48	37	s, v, v/m ?	+	+
Portesham: 153.79	806	24	53	23	s, v ?, v/m	+	+
Portesham: 152.74	807	23	61	16	s, v, v/m	+	+
Portesham: 51.30	808	16	40	44	s, v ?, v/m	?	+
Portesham: 50.46	809	13	50	37	s, v/m	-	?
Portesham: 53.25	810	21	60	19	s, v, v/m	-	+
Marton: 18.10	814	30	53	17	v, v/m	?	+
Marton: 40.37	815	28	38	34	s, v, v/m	+	+
Marton: 63.50	816	39	28	33	s, v, v/m	-	+
Marton: 162.50	817	31	50	19	v, v/m	?	+
Marton: 139.70	818	43	47	10	s ?, v, v/m	?	+
Marton: 180.75	819	38	40	22	v, v/m	+	+
Marton: 74.90	820	35	57	8	v, v/m	+	+
Marton: 108.05	821	44	36	20	v, v/m	+	+
Marton: 121.80	822	43	33	24	s, v, v/m	?	+
Marton: 206.00	823	29**	40	31	v, v/m	?	+

Borehole and depth (m)	Sample no. (KOS)	Kaolinite %	Clay mica %	Expansible minerals		Chlorite	Chlorite/mica
				Total %	Type		
Reighton: 73.00	824	41**	28	31	s, v, v/m	?	+
Reighton: 79.35	825	30**	45	25	s, v, v/m	+	+
Reighton: 89.08	826	24**	45	31	s, v, v/m	+	+
Reighton: 93.32	827	22**	43	35	v, v/m	–	+
Reighton: 101.12	828	30	41	29	s ?, v, v/m	+	+
Reighton: 105.46	829	38	28	34	s, v, v/m	?	+
Reighton: 123.85	830	38	40	22	v, v/m	+	+
Reighton: 129.39	831	30	41	29	s ?, v, v/m	+	+
Reighton: 136.75	832	32**	48	20	s ?, v, v/m	?	+
Reighton: 140.16	833	20**	50	30	v, v/m	+	+
Reighton: 143.20	834	26	54	20	s ?, v, v/m	+	+
Reighton: 146.48	835	24	51	25	s ?, v, v/m	+	+
Reighton: 152.65	836	19	46	35	s ?, v, v/m	++	+
Reighton: 157.43	837	19	67	14	v, v/m	++	+
Reighton: 160.78	838	22**	50	28	s ?, v, v/m	?	+
Donington B: 114.00	845	23	38	39	s, v	+	?
Donington B: 141.80	846	17	45	38	s, v, v/m	+	+
Hartwell: 19.10	847	6	27	67	s*	–	–
Swindon: 31.24	848	12	46	42	s*, v, v/m	–	–
Encombe: 41.52	849	15	52	33	s, v, v/m	–	+
Encombe: 20.00	850	16	47	37	s, v, v/m	–	+
Tisbury: 41.70	851	12	33	55	s*	+	–
Tisbury: 62.10	852	18	37	45	s*, v	–	+
W. Lavington: 70.56	853	16	37	47	s*, v, v/m	–	+
W. Lavington: 57.00	854	17	41	42	s*, v, v/m	–	?
Portesham: 44.74 to 46.74	1000	21	52	27	s ?, v ?, v/m	+	+
Portesham: 49.74 to 51.24	1001	19	63	18	v, v/m	+	+
Portesham: 52.24 to 54.24	1002†	19	61	20	v/m	–	+
Portesham: 62.74 to 64.74	1003	18	31	51	v, v/m	–	?
Portesham: 72.24 to 74.24	1004	20	44	36	v/m	–	+
Portesham: 92.74 to 94.74	1005	27	46	27	v/m	–	?
Portesham: 101.24 to 103.24	1006	27	59	14	v/m	–	+
Portesham: 115.24 to 117.24	1007	24	52	24	s ?, v, v/m	?	+

Borehole and depth (m)	Sample no. (KOS)	Kaolinite %	Clay mica %	Expansible minerals		Chlorite	Chlorite/mica
				Total %	Type		
Portesham: 123.24 to 125.24	1008	27	63	10	v, v/m	+	+
Portesham: 133.24 to 135.24	1009	26	47	27	v, v/m	-	+
Portesham: 138.24 to 140.24	1010	30	57	13	v, v/m	-	+
Portesham: 145.24 to 147.24	1011	26	45	21	v, v/m	-	?
Portesham: 150.24 to 152.24	1012	34	57	9	s, v, v/m	+	+
Portesham: 176.24 to 178.24	1013	27	47	26	v, v/m	-	+
Portesham: 184.24 to 185.24	1014	24	51	25	v, v/m	+	+
Tisbury: 139.25 to 140.25	1015	22	52	26	s ?, v, v/m	+	+
Tisbury: 154.75 to 156.75	1016	20	59	21	v, v/m	+	+
Tisbury: 165.25 to 167.25	1017	18	42	40	v, v/m	-	+
Tisbury: 168.25 to 170.25	1018	19	49	32	v, v/m	-	+
Tisbury: 176.25 to 178.25	1019	24	49	27	v, v/m	?	+
Tisbury: 193.75 to 194.25	1020	26	48	26	v, v/m	-	+
Tisbury: 213.75 to 215.75	1022	25	42	33	v, v/m	+	+
Tisbury: 216.25 to 217.25	1023	24	45	31	v, v/m	-	+
Tisbury: 221.75 to 223.75	1024	23	44	33	v, v/m	?	+
Tisbury: 230.25 to 232.25	1025	26	53	21	v, v/m	+	+
Tisbury: 234.75 to 235.75	1026	28	45	27	s ?, v, v/m	-	+
Tisbury: 256.75 to 258.75	1027	23	68	9	s ?, v, v/m	+	+
Kimmeridge Bay: 31.25 to 33.25	1028	25	52	23	v, v/m	-	+
Kimmeridge Bay: 36.25 to 38.25	1029	26	47	27	v, v/m	+	+
Kimmeridge Bay: 43.25 to 45.25	1030	23	51	26	v, v/m	?	+
Kimmeridge Bay: 50.25 to 52.25	1031	26	57	17	v, v/m	-	+
Kimmeridge Bay: 56.75 to 58.25	1032	27	44	29	v, v/m	-	?
Kimmeridge Bay: 66.75 to 68.75	1033	27	61	12	v, v/m	+	+
Encombe: 62.25 to 64.25	1034	20	47	33	v, v/m	-	?
Encombe: 77.25 to 79.25	1035	19	57	24	v, v/m	-	?
Encombe: 81.75 to 83.75	1036	20	70	10	v, v/m	+	+
Encombe: 117.75 to 119.75	1037	23	66	11	v, v/m	?	+
Encombe: 122.25 to 124.25	1038	22	55	23	v, v/m	-	?
Encombe: 131.25 to 132.25	1039	24	51	25	v, v/m	-	+
Hartwell: 21.90	1040	18	50	32	s*, v, v/m	+	+
Hartwell: 26.00	1041	21	44	35	s, v, v/m	+	+

Borehole and depth (m)	Sample no. (KOS)	Kaolinite %	Clay mica %	Expansible minerals		Chlorite	Chlorite/mica
				Total %	Type		
Hartwell: 31.77	1042	22	45	33	s ?, v, v/m	?	+
Hartwell: 36.65	1043	23	42	35	s ?, v, v/m	+	+
Hartwell: 41.60	1044	24	51	25	s ?, v, v/m	+	+
Hartwell: 47.24	1045	20	49	31	s, v, v/m	?	+
Hartwell: 51.42	1046	25	50	25	s, v, v/m	+	+
Hartwell: 54.98	1047	23	50	27	s, v, v/m	+	+
Hartwell: 58.80	1048	17	76	7	v, v/m	++	+
Hartwell: 62.75	1049	13	67	20	s ?, v/m	++	+
Swindon: 50.95	1050†	20	54	26	s*, v/m	-	+
Swindon: 56.75	1051	20**	44	36	s ?, v, v/m	?	+
Swindon: 65.48	1052	20	45	35	s, v, v/m	?	+
Swindon: 69.00	1053	19	47	34	s, v, v/m	+	+
Swindon: 78.58	1054	23	50	27	s ?, v, v/m	+	+
Swindon: 87.45	1055†	18	62	20	v, v/m	++	+
Foudry Bridge: 464.56	1056	25	63	12	v, v/m	+	+
Foudry Bridge: 460.88	1057	20	68	12	v, v/m	+	+
Foudry Bridge: 463.29	1058†	23	77	<1	v, v/m	+	+
Foudry Bridge: 458.57	1059	19	46	35	v, v/m	+	+
Foudry Bridge: 465.41	1060	25	55	20	s ?, v, v/m	+	+
Foudry Bridge: 450.37	1061†	18	46	36	v, v/m	+	+
Foudry Bridge: 448.87	1062	19	74	7	v, v/m	+	+
Foudry Bridge: 447.29	1063	16	54	30	v, v/m	+	+
Foudry Bridge: 445.80	1064†	24	72	4	v, v/m	-	+
Foudry Bridge: 444.02	1065	14	48	38	v, v/m	-	+
Warlingham: 703.48	1066	20	43	37	v, v/m	-	+
Warlingham: 720.29	1067	17	60	23	v, v/m	+	+
Warlingham: 726.87	1068	16	64	20	v, v/m	+	+
Warlingham: 731.11	1069	15	63	22	v, v/m	+	+
Warlingham: 739.93	1070	18	59	23	v, v/m	+	+
Warlingham: 746.84	1071	16	67	17	v, v/m	+	+
Warlingham: 757.05	1072	23	52	25	v, v/m	+	+
Warlingham: 770.92	1073	20	69	11	v, v/m	++	+
Warlingham: 788.52	1074†	23	77	<1	v ?, v/m ?	+	+

Borehole and depth (m)	Sample no. (KOS)	Kaolinite %	Clay mica %	Expansible minerals		Chlorite	Chlorite/mica
				Total %	Type		
Warlingham: 793.60	1075	27	66	7	v, v/m	++	+
Warlingham: 803.10	1076	15	54	31	s ?, v, v/m	++	+
Warlingham: 822.70	1077	19	58	23	s ?, v, v/m	++	+
Warlingham: 832.92	1078	21	48	31	v, v/m	++	+
Warlingham: 850.04	1079	20	61	19	v, v/m	++	+
Warlingham: 879.04	1080	14	57	29	v, v/m	++	+
Encombe: 8.45	1081	15	46	39	v, v/m	+	+
W. Lavington: 173.25 to 173.50	1082	23	49	28	v, v/m	+	+
W. Lavington: 169.25 to 169.50	1083	21	48	31	v, v/m	?	+
W. Lavington: 159.75 to 160.00	1084	22	50	28	v, v/m	++	+
W. Lavington: 157.00 to 157.25	1085	27	49	24	v, v/m	-	+
W. Lavington: 154.00 to 154.25	1086	23	50	27	v, v/m	+	+
W. Lavington: 161.50 to 161.75	1087	22	56	22	v, v/m	+	+
W. Lavington: 165.75 to 166.00	1088	20	53	27	v, v/m	+	+
W. Lavington: 148.75 to 149.00	1089	24	47	29	v, v/m	-	-
N. Runcton: 12.00 to 12.50	1090	22	49	29	v, v/m	+	+
N. Runcton: 23.50 to 25.50	1091	19**	51	30	v, v/m	-	+
N. Runcton: 35.50 to 37.50	1092	22**	48	30	v, v/m	+	+
N. Runcton: 47.75 to 49.75	1093	22	68	10	v, v/m	+	+
N. Runcton: 52.25 to 54.25	1094	23	62	15	v, v/m	+	+
N. Runcton: 62.50 to 63.00	1095	20	71	9	v, v/m	?	+
Donington B: 25.30 to 26.30	1096	29	58	13	s ?, v, v/m	+	+
Donington B: 32.30 to 33.80	1097	23	51	26	v, v/m	-	+
Donington B: 43.55 to 45.55	1098	23	52	25	v, v/m	+	+
Donington B: 63.50 to 65.50	1099	29**	51	20	v, v/m	+	+
Donington B: 82.25 to 84.25	1100	29	51	20	s ?, v, v/m	-	+
Donington B: 92.25	1101	33	56	11	v, v/m	+	+
Donington B: 107.75	1102	25	45	30	v, v/m	-	+
Swindon: 110.84	1103	18	63	19	v, v/m	+	+
Foudry Bridge: 435.74	1104	24**	55	21	v, v/m	?	+
Foudry Bridge: 422.80	1105	21	48	31	v, v/m	-	+
Foudry Bridge: 416.00	1106	22	51	27	s ?, v, v/m	-	+
Warlington: 851.71	1107	21	61	18	v, v/m	++	+
Portesham: 13.80	1108	21	58	21	v, v/m	+	+
W. Lavington: 114.50	1109	27**	44	29	v, v/m	+	+

KIMMERIDGE OIL SHALES SAMPLE NUMBERS 147-152

ELEMENT	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MAXIMUM VALUE	MINIMUM VALUE	NUMBER OF DETERMINATIONS
IN	878.833	50.129	5.7	952.00	800.00	6
EU	758.500	42.857	5.6	827.00	703.00	6
PT	497.666	91.670	18.4	619.00	350.00	6
LI	52.650	2.679	5.0	56.40	49.50	6
BE	1.333	0.445	33.4	2.00	0.80	6
B	148.000	29.414	19.8	186.00	115.00	6
MGO	1.274	0.187	14.7	1.64	1.09	6
AL2O3	16.149	2.198	13.6	18.40	13.20	6
SIO2	42.816	5.923	13.8	52.10	36.30	6
K2O	2.633	0.366	13.9	3.28	2.20	6
CAO	8.334	1.365	16.3	9.46	6.02	6
TIO2	0.841	0.063	7.5	0.92	0.76	6
V	141.166	41.402	29.3	181.00	93.00	6
CR	78.666	7.737	9.8	92.00	70.00	6
MN	126.000	13.971	11.0	146.00	108.00	6
FE2O3	5.041	0.311	6.1	5.45	4.76	6
CO	11.000	5.513	50.1	22.00	8.00	6
NI	54.500	12.817	23.5	69.00	35.00	6
CU	43.833	11.232	25.6	60.00	28.00	6
ZN	158.333	41.005	25.8	233.00	108.00	6
GA	13.666	1.838	13.4	16.80	11.50	6
GE	0.000	0.000	0.0	0.00	0.00	6
RB	169.166	31.320	18.5	210.00	133.00	6
SR	391.500	23.330	5.9	420.00	364.00	6
Y	41.500	3.937	9.4	46.00	35.00	6
ZR	81.166	31.198	38.4	134.00	39.00	6
MO	14.000	15.059	107.5	39.00	0.00	6
AG	0.216	0.343	158.3	0.90	0.00	6
SN	0.000	0.000	0.0	0.00	0.00	6
BA	217.833	23.827	10.9	257.00	191.00	6
LA	61.000	12.649	20.7	78.00	44.00	6
PB	5.000	2.966	59.3	8.00	1.00	6
BI	0.000	0.000	0.0	0.00	0.00	6
LI2	77.166	8.750	11.3	89.00	66.00	6
MN2	0.013	0.020	154.9	0.04	0.00	6
PB2	0.000	0.000	0.0	0.00	0.00	6
R1	647.166	29.903	4.6	695.00	612.00	6
R2	493.833	34.114	6.9	528.00	444.00	6
R3	423.933	25.980	6.1	457.00	390.00	6

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RECALC. OMITTING SAMPLES OUTSIDE RANGE MEAN PLUS OR MINUS TWICE STD DEV
KIMMERIDGE OIL SHALES SAMPLE NUMBERS 147-152


     ELEMENT          MEAN         STANDARD    COEFFICIENT OF    MAXIMUM        MINIMUM       NUMBER OF
                                   DEVIATION     VARIATION        VALUE          VALUE     DETERMINATIONS

     IN             878.833         50.129          5.7          952.00         800.00           6
     EU             758.500         42.857          5.6          827.00         703.00           6
     PT             497.666         91.670         18.4          619.00         350.00           6
     LI              52.650          2.679          5.0           56.40          49.50           6
     BE               1.333          0.445         33.4            2.00           0.80           6
     B              148.000         29.414         19.8          186.00         115.00           6
     MGO              1.274          0.187         14.7            1.64           1.09           6
     AL2O3           16.149          2.198         13.6           18.40          13.20           6
     SIO2            42.816          5.923         13.8           52.10          36.30           6
     K2O              2.633          0.366         13.9            3.28           2.20           6
     CAO              8.334          1.365         16.3            9.46           6.02           6
     TIO2             0.841          0.063          7.5            0.92           0.76           6
     V              141.166         41.402         29.3          181.00          93.00           6
     CR              78.666          7.737          9.8           92.00          70.00           6
     MN             126.000         13.971         11.0          146.00         108.00           6
     FE2O3            5.041          0.311          6.1            5.45           4.76           6
     CO              11.000          5.513         50.1           22.00           8.00           6
     NI              54.500         12.817         23.5           69.00          35.00           6
     CU              43.833         11.232         25.6           60.00          28.00           6
     ZN             158.333         41.005         25.8          233.00         108.00           6
     GA              13.666          1.838         13.4           16.80          11.50           6
     GE               0.000          0.000          0.0            0.00           0.00           6
     RB             169.166         31.320         18.5          210.00         133.00           6
     SR             391.500         23.330          5.9          420.00         364.00           6
     Y               41.500          3.937          9.4           46.00          35.00           6
     ZR              81.166         31.198         38.4          134.00          39.00           6
     MO              14.000         15.059        107.5           39.00           0.00           6
     AG               0.216          0.343        158.3            0.90           0.00           6
     SN               0.000          0.000          0.0            0.00           0.00           6
     BA             217.833         23.827         10.9          257.00         191.00           6
     LA              61.000         12.649         20.7           78.00          44.00           6
     PB               5.000          2.966         59.3            8.00           1.00           6
     BI               0.000          0.000          0.0            0.00           0.00           6
     LI2             77.166          8.750         11.3           89.00          66.00           6
     MN2              0.013          0.020        154.9            0.04           0.00           6
     PB2              0.000          0.000          0.0            0.00           0.00           6
     B1             647.166         29.903          4.6          695.00         612.00           6
     B2             493.833         34.114          6.9          528.00         444.00           6
     B3             423.833         25.980          6.1          457.00         390.00           6
     K/RB           130.666         13.063          9.9          145.00         107.00           6
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KIMMERIDGE OIL SHALES SAMPLE NUMBERS 243-321

ELEMENT	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION	MAXIMUM VALUE	MINIMUM VALUE	NUMBER OF DETERMINATIONS
IN	754.932	77.480	10.2	890.00	400.00	74
FU	716.216	101.429	14.1	936.00	357.00	74
RT	618.824	86.670	14.0	756.00	316.00	74
LI	50.610	5.377	10.6	58.10	27.60	74
BE	2.322	2.462	105.9	19.80	0.30	74
B	247.689	45.505	18.3	344.00	113.00	74
MGO	1.084	0.383	35.3	3.07	0.70	74
AL2O3	15.764	3.385	21.4	23.10	4.60	74
SIO2	53.578	9.311	17.3	70.40	34.20	74
K2O	2.757	0.562	20.4	4.27	1.50	74
CAO	4.668	2.562	54.8	12.35	0.49	74
TIO2	0.853	0.121	14.1	1.57	0.64	74
V	108.648	31.983	29.4	196.00	57.00	74
CR	80.391	12.648	15.7	108.00	51.00	74
MN	138.689	35.405	25.5	196.00	0.00	74
FE2O3	5.390	0.915	16.9	7.32	3.34	74
CO	8.702	2.098	24.1	15.00	5.00	74
NI	48.013	14.306	29.7	86.00	19.00	74
CU	35.567	8.654	24.3	57.00	20.00	74
ZN	126.662	76.124	60.1	382.00	27.00	74
GA	16.209	3.061	18.8	21.60	8.20	74
GE	1.459	2.190	150.1	8.00	0.00	74
RB	208.959	47.062	22.5	328.00	119.00	74
SR	266.797	49.430	18.5	411.00	158.00	74
Y	29.689	6.011	20.2	61.00	21.00	74
ZR	230.297	95.538	41.4	456.00	67.00	74
MO	8.918	7.877	88.3	39.00	0.00	74
AG	0.113	0.293	258.9	1.40	0.00	74
SN	0.729	1.649	226.0	7.00	0.00	74
BA	260.608	35.532	13.6	334.00	176.00	74
LA	51.324	12.043	23.4	107.00	26.00	74
PB	8.594	4.719	54.9	21.00	0.00	74
BI	2.054	3.443	167.6	20.00	0.00	74
LI2	75.864	22.595	29.7	126.00	35.00	74
MN2	0.010	0.017	166.1	0.04	0.00	74
PB2	13.256	22.688	171.1	132.00	0.00	74
R1	592.405	65.939	11.1	765.00	396.00	74
R2	412.405	70.183	17.0	677.00	273.00	74
R3	345.918	65.723	18.9	600.00	235.00	74
K/RB	110.810	14.060	12.6	151.00	79.00	74

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RECALC. OMITTING SAMPLES OUTSIDE RANGE MEAN PLUS OR MINUS TWICE STD DEV
KIMMERIDGE OIL SHALES SAMPLE NUMBERS 243-321


     ELEMENT         MEAN         STANDARD    COEFFICIENT OF    MAXIMUM        MINIMUM      NUMBER OF
                                  DEVIATION      VARIATION        VALUE          VALUE    DETERMINATIONS

     IN            762.986         60.163           7.8          890.00         603.00          72
     EU            724.785         81.841          11.2          877.00         574.00          70
     PT            631.814         68.269          10.8          756.00         451.00          70
     LI             51.316          4.102           7.9           58.10          41.80          71
     BE              2.004          1.185          59.1            6.10           0.30          72
     B             249.661         40.201          16.1          323.00         163.00          71
     MGO             1.030          0.204          19.8            1.78           0.70          72
     AL2O3          15.923          2.929          18.3           21.70           9.20          71
     SIO2           54.391          8.594          15.8           70.40          35.10          71
     K2O             2.719          0.486          17.9            3.83           1.66          70
     CAO             4.383          2.187          49.9            9.52           0.49          71
     TIO2            0.843          0.087          10.3            1.05           0.64          73
     V             104.171         26.481          25.4          171.00          57.00          70
     CR             80.788         11.554          14.3          103.00          57.00          71
     MN            144.549         21.167          14.6          196.00         110.00          71
     FE2O3           5.366          0.842          15.7            7.22           3.78          71
     CO              8.333          1.623          19.4           12.00           5.00          69
     NI             46.463         11.677          25.1           71.00          25.00          69
     CU             35.013          8.090          23.1           50.00          20.00          72
     ZN            111.202         50.597          45.5          273.00          27.00          69
     GA             16.504          2.752          16.6           21.60          10.40          71
     GE              0.925          1.480         159.9            5.00           0.00          67
     RB            204.549         42.644          20.8          300.00         119.00          71
     SR            264.746         43.636          16.4          362.00         175.00          71
     Y              28.845          4.121          14.2           39.00          21.00          71
     ZR            218.157         82.957          38.0          399.00          67.00          70
     MO              7.132          5.072          71.1           22.00           0.00          68
     AG              0.054          0.153         283.4            0.60           0.00          70
     SN              0.457          1.200         262.5            4.00           0.00          70
     BA            264.072         30.068          11.3          329.00         191.00          69
     LA             50.492          9.239          18.2           74.00          30.00          71
     PB              8.263          4.334          52.4           18.00           0.00          72
     BI              1.563          2.328         148.9            8.00           0.00          71
     LI2            75.178         21.960          29.2          117.00          35.00          73
     MN2             0.010          0.017         166.1            0.04           0.00          74
     PB2             8.739         13.689         156.6           48.00           0.00          69
     B1            593.100         54.727           9.2          715.00         490.00          70
     B2            405.861         58.598          14.4          550.00         273.00          72
     B3            339.805         54.830          16.1          470.00         235.00          72
     K/RB          110.253         12.426          11.2          138.00          87.00          71
```

Appendix G:
Details of boreholes referred to in the text

Table G1 Boreholes referred to in the text

– . . . horizon not proved

Borehole	Datum (m above OD)	Depth to K. C. top (m)	Elevation of K. C. top (m above OD)	Depth to K. C. base (m)	Elevation of K. C. base (m above OD)	K. C. thickness (m)	Grid Reference
Abbotscliffe	26	164	-138	210	-184	46	TR 266 385
Arreton No. 1	38	808	-770	1145	-1107	337	SZ 5307 8564
Arreton No. 2	32	810	-778	1147	-1115	337	SZ 5320 8580
Ashdown No. 1	190	360	-170	920	-730	560	TQ 5005 3035
Ashdown No. 2	178	381	-203	908	-730	527	TQ 5107 2924
Battle	37	290	-254	-	-	341+	TQ 7560 1720
Baulking No. 2	81	32	49	41	40	9	SU 3269 9050
Bletchingley No. 1	65	564	-499	988	-923	424	TQ 3662 4773
Bletchingley No. 2	66	598	-532	969	-903	372	TQ 3553 4794
Bletchingley No. 3	88	614	-526	914	-826	300	TQ 3275 4876
Bletchingley No. 4	80	658	-578	1036	-956	378	TQ 3493 4838
Bolney	74	431	-357	986	-912	555	TQ 2801 2427
Brabourne	66	217	-151	297	-231	80	TR 0776 4231
Brightling	153	144	8	490	-338	346	TQ 6725 2182
Chaldon Down	111	482	-370	-	-	65+	SY 8323 8130
Chaldon Herring	79	143	-64	402	-323	259	SY 7837 8402
Collendean Farm	89	724	-635	1170	-1081	446	TQ 2480 4429
Cowden	132	456	-324	992	-860	536	TQ 4661 4278
Cranbourne	65(e)	518	-453(e)	559	-494(e)	41	SU 0341 0907
Cumnor	124	-	-	7	117	7+	SP 4783 0337
Devizes	55	-	-	43	-12	43+	ST 9605 5695
Donington on Bain	73	23	50	195	-122	172	TF 2399 8188
Elham	84	219	-135	280	-196	61	TR 1800 4380
Ellinge	122	283	-161	340	-218	57	TR 249 428
Encombe	86	-	-	541	-455	541+	SY 9412 7832
Farthingloe	70	216	-146	226	-156	10	TR 287 401
Folkstone	34	169	-134	233	-198	64	TR 2403 3675
Fordingbridge	69	686	-617	750	-681	64	SU 1876 1180
Fordon	63	323	-260	712	-649	390	TA 0592 7575
Foudry Bridge	58	410	-352	494	-436	84	SU 7033 6604
Haddenham	15	12	3	33	-18	21	4660 7554
Hartwell	100	18	82	70	30	52	SP 7926 1223

Borehole	Datum (m above OD)	Depth to K. C. top (m)	Elevation of K. C. top (m above OD)	Depth to K.C. base (m)	Elevation of K. C. base (m above OD)	K. C. thickness (m)	Grid Reference
Hellingly	56	335	-279	680	-624	345	TQ 6010 1358
Henfield	11	469	-458	799	-788	330	TQ 1799 1457
Hunmanby	-	137	-	233	-	96	TA 1301 7598
Hunstanton	11	101	-90	193	-182	92	TF 6923 4270
Kimmeridge No. 2	45	-	-	320	-275	320+	SY 9114 7915
Kingsclere	163	524	-361	805	-642	281	SU 4984 5820
Leigh	59	747	-688	-	-	155+	TQ 2170 4751
Malton	23	-	-	45	-22	45+	SE 7096 7048
Marton	162	-	-	-	-	212+	SE 7230 8285
Middleton	3	587	-584	813	-811	226	SU 9739 0150
Nettleton	166	65	101	352	186	287	TF 1185 9642
North Creake	22	214	-193	263	-241	49	TF 8568 3864
North Runcton	16	9	7	102	-87	93	TF 6404 1624
Osmington	33	-	-	116	-83	116+	SY 717 836
Penshurst	30	358	-327	801	-771	443	TQ 5542 1443
Pluckley	32	354	-322	-	-	160+	TQ 9240 4330
Portesham	67	-	-	-	-	210+	SY 6214 8554
Portsdown No. 1	68	782	-714	1117	-1049	335	SU 6380 0652
Poxwell	141	49	92	303	-162	254	SY 7490 8362
Reighton	55	-	-	-	-	87+	TA 1465 7581
Shalford	49	875	-877	1262	-1213	386	SU 9821 4680
Shapwick	25	429	-404	-	-	66+	ST 9428 0134
South Creake	42	227	-185	273	-231	46	TF 8573 3402
Southery	3	31	-28	69	-66	38	TL 693 965
Strat. A (Esso)	42	677	-635	-	-	62+	SU 9478 5278
Strat. B (Esso)	57	429	-372	567	-510	138	SU 6822 6522
Sub-Wealden	46	83	-38	477	-431	393	TQ 7194 1930
Swindon	143	2	141	115	-28	113	SU 1413 8349
Tatsfield	213	719	-506	879	-666	160	TQ 4245 5705
Tisbury	137	20	117	-	-	210+	ST 9359 2907
Wareham	8	550	-542	663	-655	113	SY 9091 8783
Warlingham	106	693	-588	910	-805	217	TQ 3476 5719
Westham	9	274	-266	470	-461	196	TQ 6097 0535
Winchester No. 1	66	693	-628	1040	-974	346	SU 5034 2849

Borehole	Datum (m above OD)	Depth to K. C. top (m)	Elevation of K. C. top (m above OD)	Depth to K. C. base (m)	Elevation of K. C. base (m above OD)	K. C. thickness (m)	Grid Reference
Winestead	-	366	-	505	-	139	TA 1900 4328
Winterbourne	60	344	-284	393	-333	49	SY 8469 9798
Woodlands	55	610	-555	620	-665	-10	SU 6590 6272
Ulceby Cross	101	141	-30	?474	?373	?333	
West Lavington	83	8	75	-	-	223+	ST 9898 5633
47/3-1	28	823	-795	862	-834	39	53° 56'N 00° 34'E
47/15-1X	26	884	-858	919	-893	35	53° 37'N 00° 55'E
47/18-1	36	545	-509	780	-744	235	53° 25'N 00° 33'E
47/29A-1	29	456	-428	537	-508	81	53° 09'N 00° 37'E
48/11-1	25	1000	-975	1039	-1014	39	53° 33'N 01° 08'E
48/17-1	33	559	-526	674	-641	115	
48/22-2	28	435	-407	560	-532	125	53° 15'N 01° 55'E
48/23-1	30	906	-876	1075	-1045	169	53° 14'N 01° 32'E

Kimmeridge Clay was proved to be absent in the following boreholes

Ashwell [TL 2860 3900]
Atwick [TA 1763 5141]
Barmston [TA 1545 6062]
Bere Regis [SY 8644 9563]
Bobbing [TQ 8748 6518]
Breckles [TL 9551 9469]
Brown Moor [SE 8126 6203]
Ellingham [TM 0262 9847]
Fobbing [TQ 7151 8422]
Great Hatfield [TA 1900 4328]
Harmondsworth [TQ 0683 7713]
Harmonsole [TR 1415 5289]
Hornsea [TA 1185 4506]
Kingsdown [TR 3717 4922]
Lakenheath [TL 7480 8300]
Maidenhead [SU 8825 8135]
Marlow [SU 8424 8679]
North Dalton [SE 9382 5277]
Richmond [TQ 1764 7469]
Risby [TA 0106 3578]
Rocklands [TL 9952 9670]
Saxthorpe [TG 1226 3013]
Soham [TL 5928 7448]
Sonning Eye [SU 7420 7580]
South Cave [SE 9366 3230]
Streatham [TQ 2956 7103]
Tring [SP 9121 1036]
Trunch [TG 294 345]
Wytch Farm [SY 9804 8536]

Table G2 Norfolk Oil Shale Boreholes 1916-1923

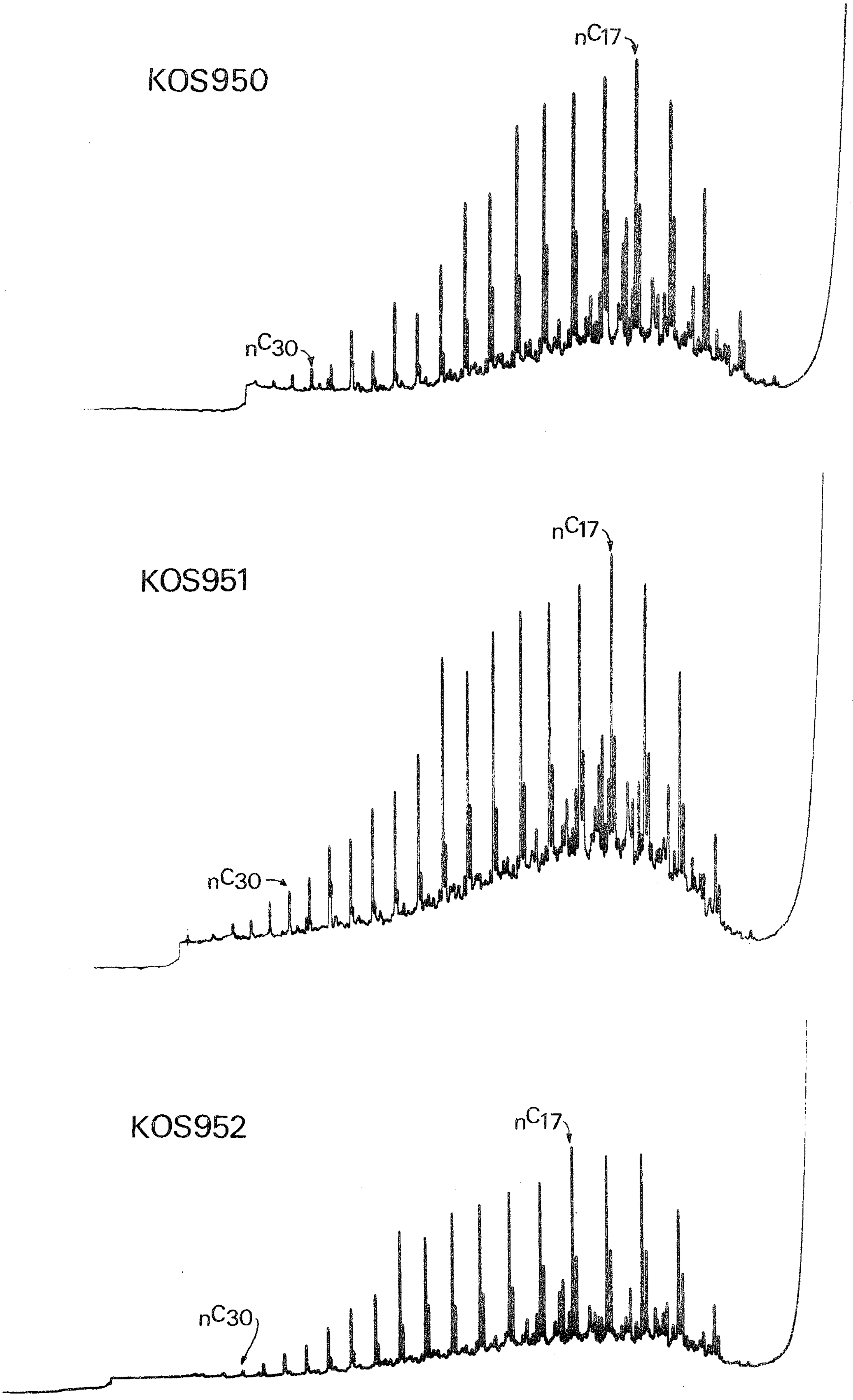
Key to companies:				
EOL	English Oilfields Ltd		WS	Wissington Syndicate
NOSS	Norfolk Oil Shale Syndicate		PS	Pentney Syndicate
FOSS	Finchham Oil Shale Syndicate			

Site No. in Fig. 24	Borehole name	Grid Reference (TF)	Company	IGS Records Room No.	Geological data available * = yes † = no
1	Gaywood Bridge	6480 2158	NOSS	TF 62 SW 100	*
2	Gaywood	6529 2132	EOL		†
3	EOL 19	6330 1835	EOL		†
4	EOL No. 7 East (Hardwick)	6405 1829	EOL		†
5	Whitehouse Farm, Mintlyn	6650 1842	NOSS	TF 61 NE 10	*
6	EOL 47	6257 1742	EOL		*
7	EOL 49	6335 1720	EOL		†
8	Fair Green, Middleton	6520 1684	NOSS	TF 61 NE 9	*
9	East Walton	7251 1670	PS	TF 71 NW 50	*
10	EOL No. 3 East (West Winch)	6366 1628	EOL	TF 61 NW 239	*
11	EOL No. 4 West (Saddlebow)	6160 1609	EOL		†
12	EOL No. 1 East (J. Cooper's Field)	6280 1585	EOL		†
13	East Winch Hall	7037 1593	PS	TF 71 NW 17	*
14	EOL 44	6408 1510	EOL		†
15	EOL 32	6338 1493	EOL		†
16	EOL No. 2 East (Manor Farm, Blackborough)	6534 1490	EOL		†
17	Magpie Farm, Pentney	7283 1492	PS	TF 71 SW 39	*
18	EOL No. 3 West (Smith's Marsh)	6228 1482	EOL		†
19	EOL No. 2 West (Nar Bank)	6194 1463	EOL		†
20	EOL 21 (Setchey Mine)	6240 1453	EOL	TF 61 SW 34	*
21	EOL 39	6284 1470	EOL		†
22	EOL 27	6316 1483	EOL		†
23	EOL 38	6317 1468	EOL		†
24	EOL 40	6343 1480	EOL		†
25	EOL 26	6335 1463	EOL		†

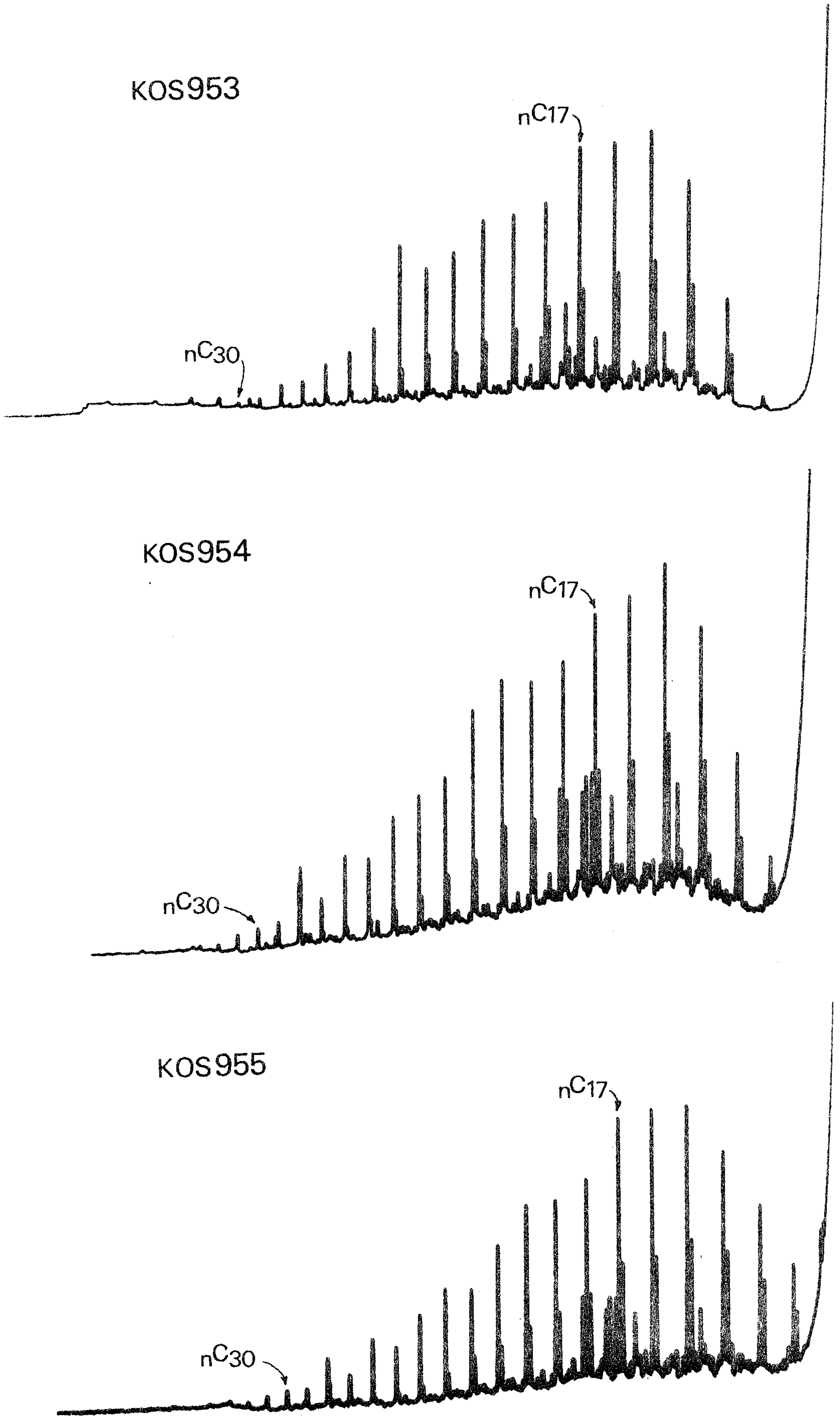
Site No. in Fig. 24	Borehole name	Grid Reference (TF)	Company	IGS Records Room No.	Geological data available * = yes † = no
26	EOL 34	6338 1453	EOL		†
27	EOL 33	6339 1444	EOL		†
28	EOL 42	6338 1425	EOL		†
29	EOL 35	6326 1451	EOL		†
30	EOL 36	6313 1447	EOL		†
31	EOL 37	6303 1442	EOL		†
32	EOL 28	6330 1443	EOL		†
33	EOL No. 4 East Jones Farm, Nar River	6350 1400	EOL		†
34	EOL 18	6370 1383	EOL		†
35	EOL No. 6 East (Setch Fen)	6402 1368	EOL		†
36	EOL 41	6415 1329	EOL		†
37	EOL No. 41 East (White House Farm, West Bilney)	6997 1310	EOL	TF 61 SE 8	*
38	Ashwood Lodge, Pentney	7077 1250	PS	TF 71 SW 40	
39	EOL 20	6582 1173	EOL		†
40	EOL No. 4 South (Tottenhill Row)	6297 1163	EOL		†
41	EOL 29	6585 1154	EOL		†
42	EOL 22	6722 1141	EOL		†
43	EOL No. 5 East (Wormegay)	6591 1134	EOL	TF 61 SE 5	*
44	EOL 48	6602 1073	EOL		†
45	EOL 45 (West Briggs)	6 30 1059	EOL	TF 61 SE 6	*
46	EOL 30	6796 1036	EOL		†
47	EOL 54	7070 0966	EOL		†
48	EOL 51	6405 0937	EOL		†
49	EOL No. 2 (South Holme)	6252 0840	EOL		†
50	EOL 53	5890 0734	EOL		†
51	EOL No. 5 South (Stowbridge No. 2)	5882 0720	EOL		†
52	EOL No. 3 South (Stowbridge)	6072 0664	EOL	TF 60 NW 12	*

Site No. in Fig. 24	Borehole name	Grid Reference (TF)	Company	IGS Records Room No.	Geological data available * = yes † = no
53	EOL 52	6585 0704	EOL		†
54	EOL 24	6516 0515	EOL		†
55	Fincham	6886 0508	FOSS	TF 60 NE 1	*
56	EOL 50	6804 0365	EOL		†
57	EOL 46	6635 0201	EOL		†
58	EOL No. 6 South (Wretton)	6803 9890	EOL	TL 69 NE 8	*
59	Methwold No. 3 (=Severals House)	6921 9639	WS	TL 69 NE 9	*
60	Methwold No. 1 (=Decoy Farm)	6487 9476	WS	TL 69 SW 140	*
61	Methwold No. 2 (=Methwold Common)	6758 9419	WS	TL 69 SE 2	*
62	EOL 43	6582 1164	EOL		†
63	Shouldham Common	672 104	PS	TF 61 SE 7	*

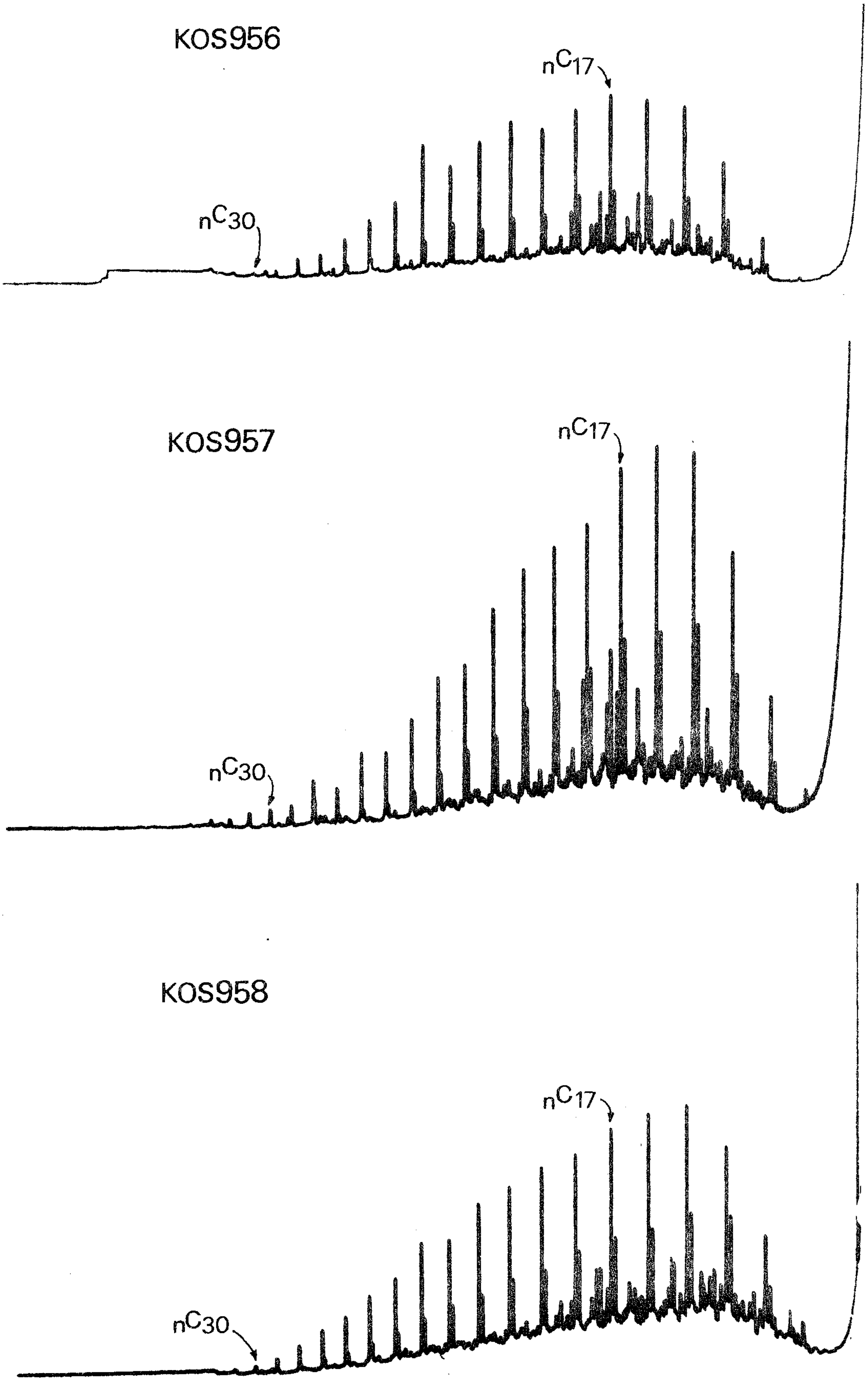
Appendix H:
Gas chromatograms



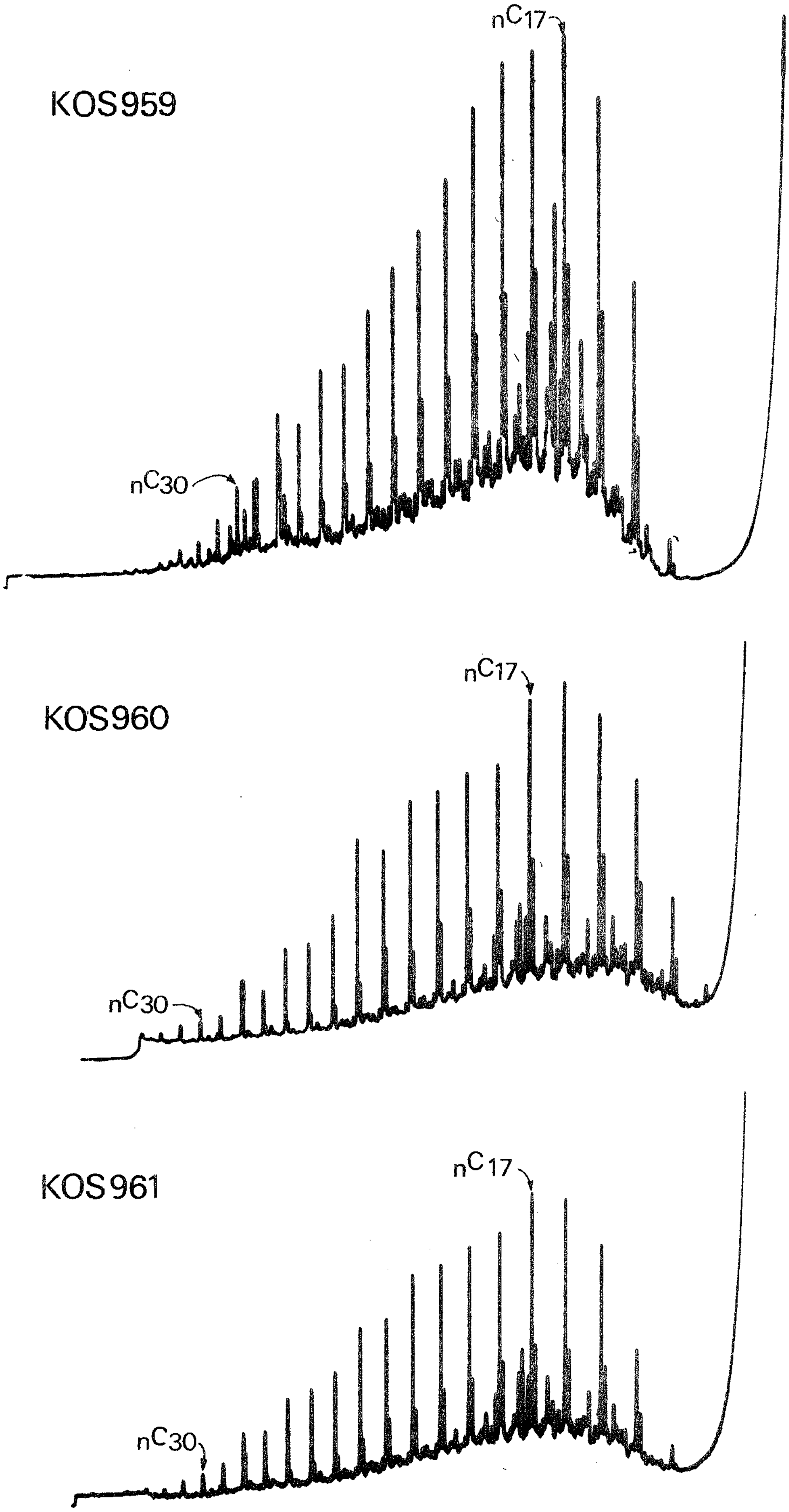
Shale oils: alkane/alkene fractions



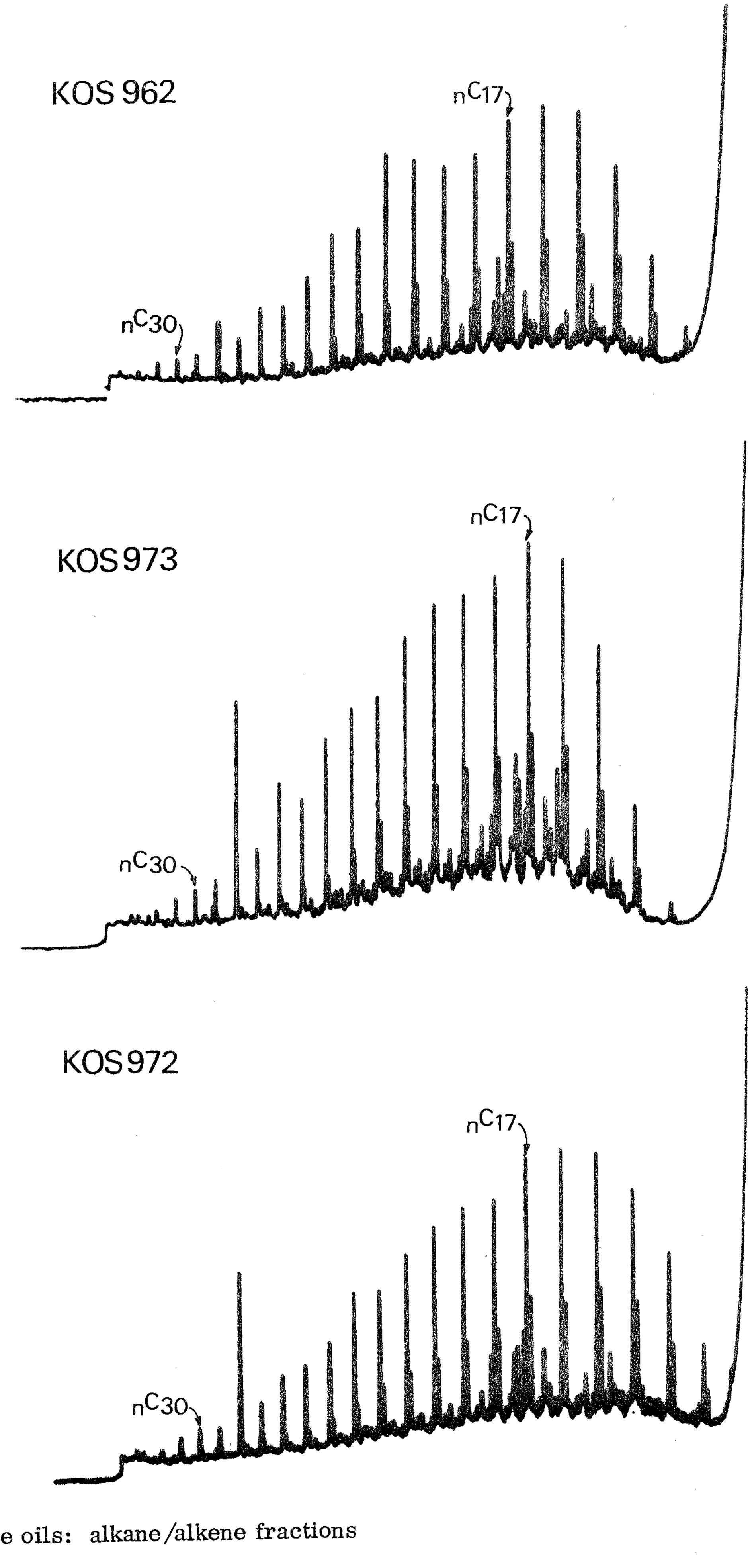
Shale oils: alkane/alkene fractions



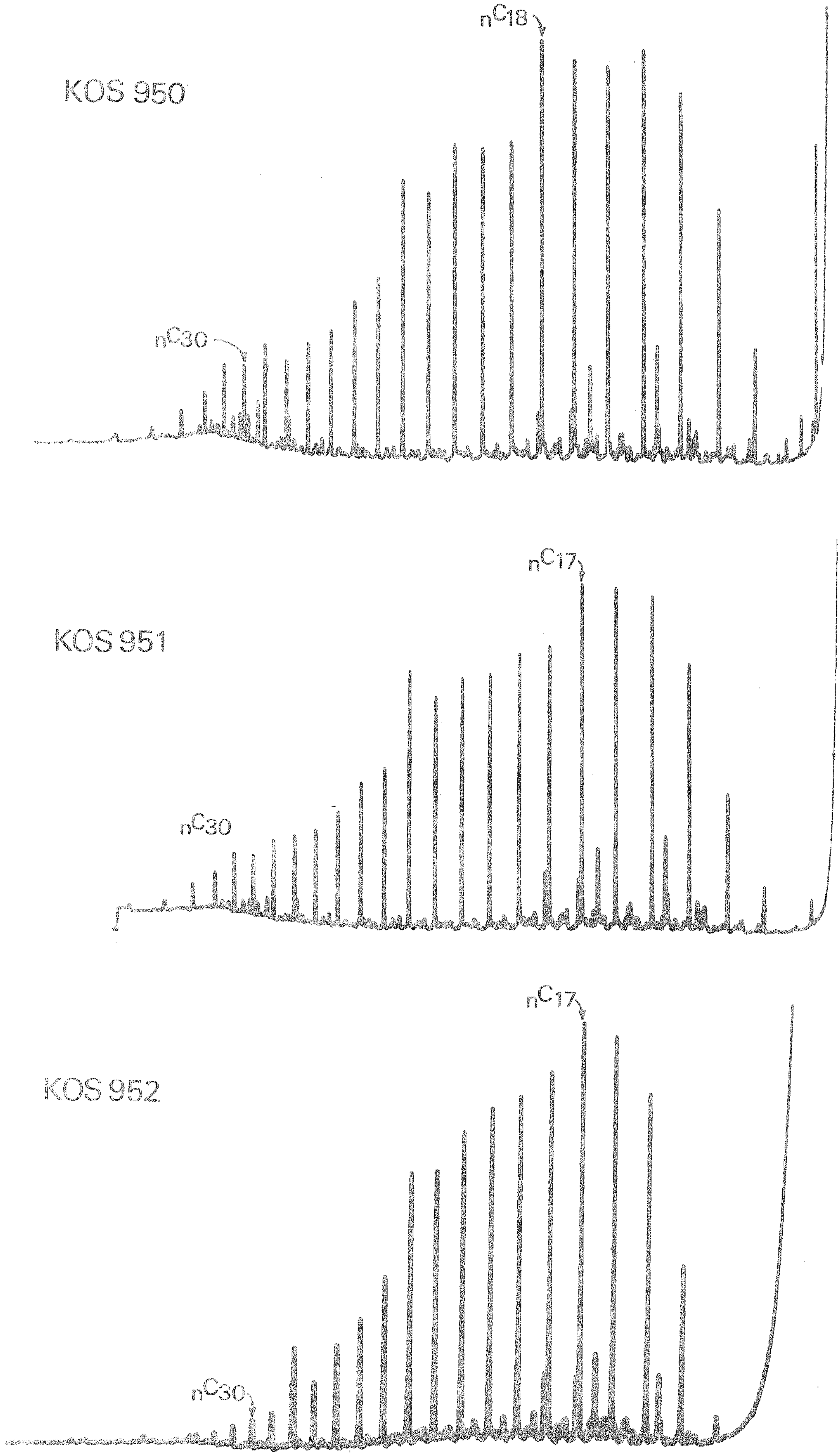
Shale oils: alkane/alkene fractions



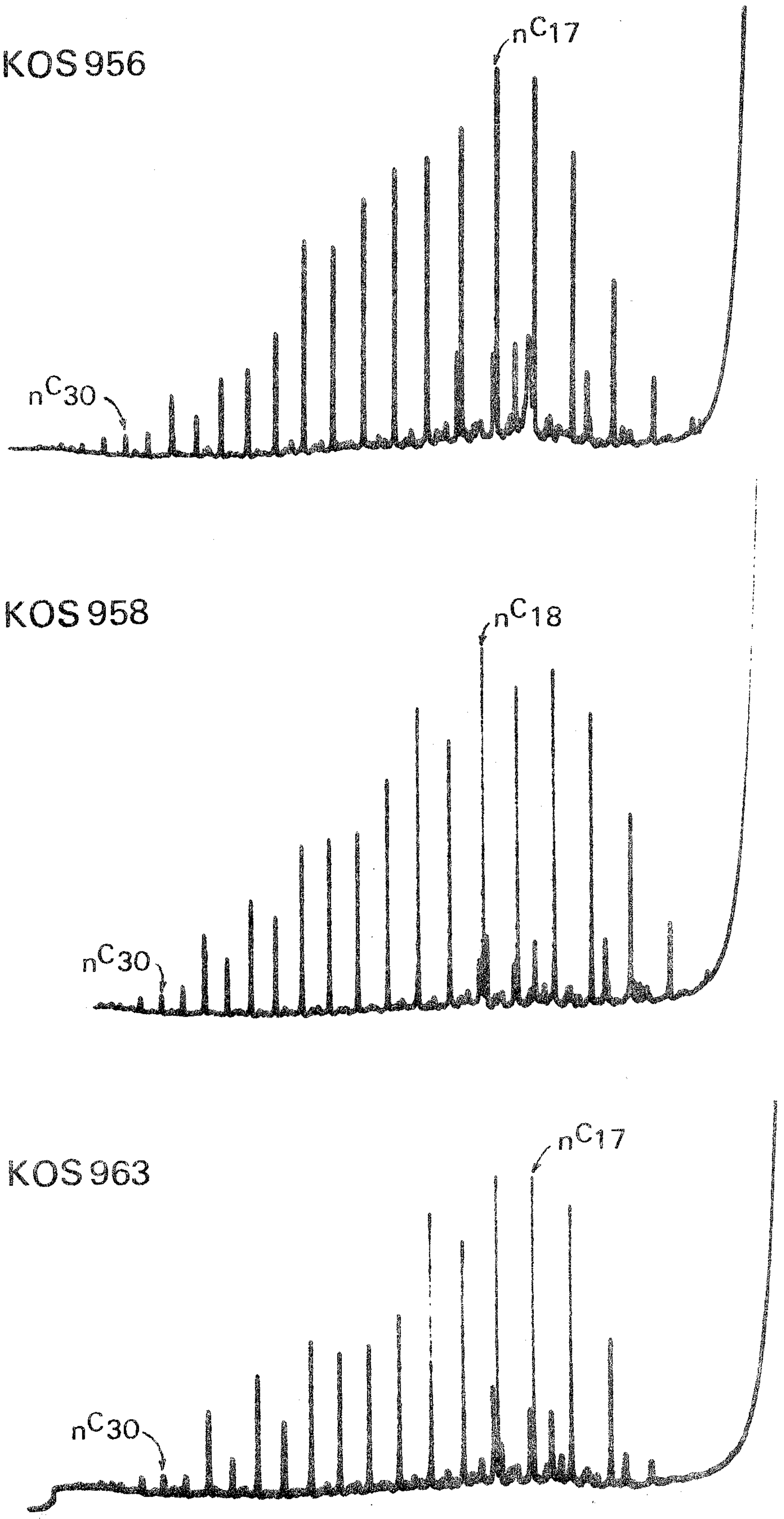
Shale oils: alkane/alkene fractions



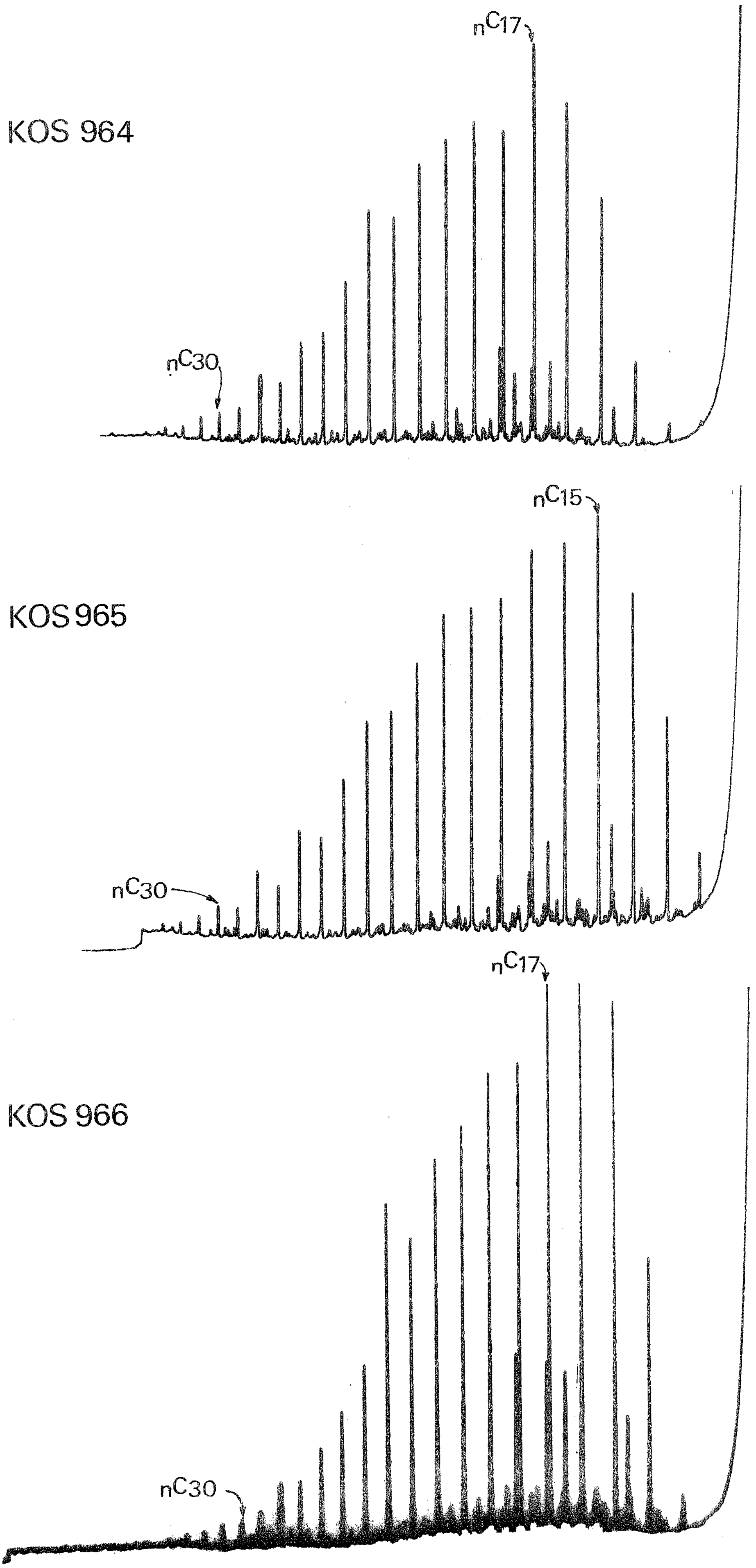
Shale oils: alkane/alkene fractions



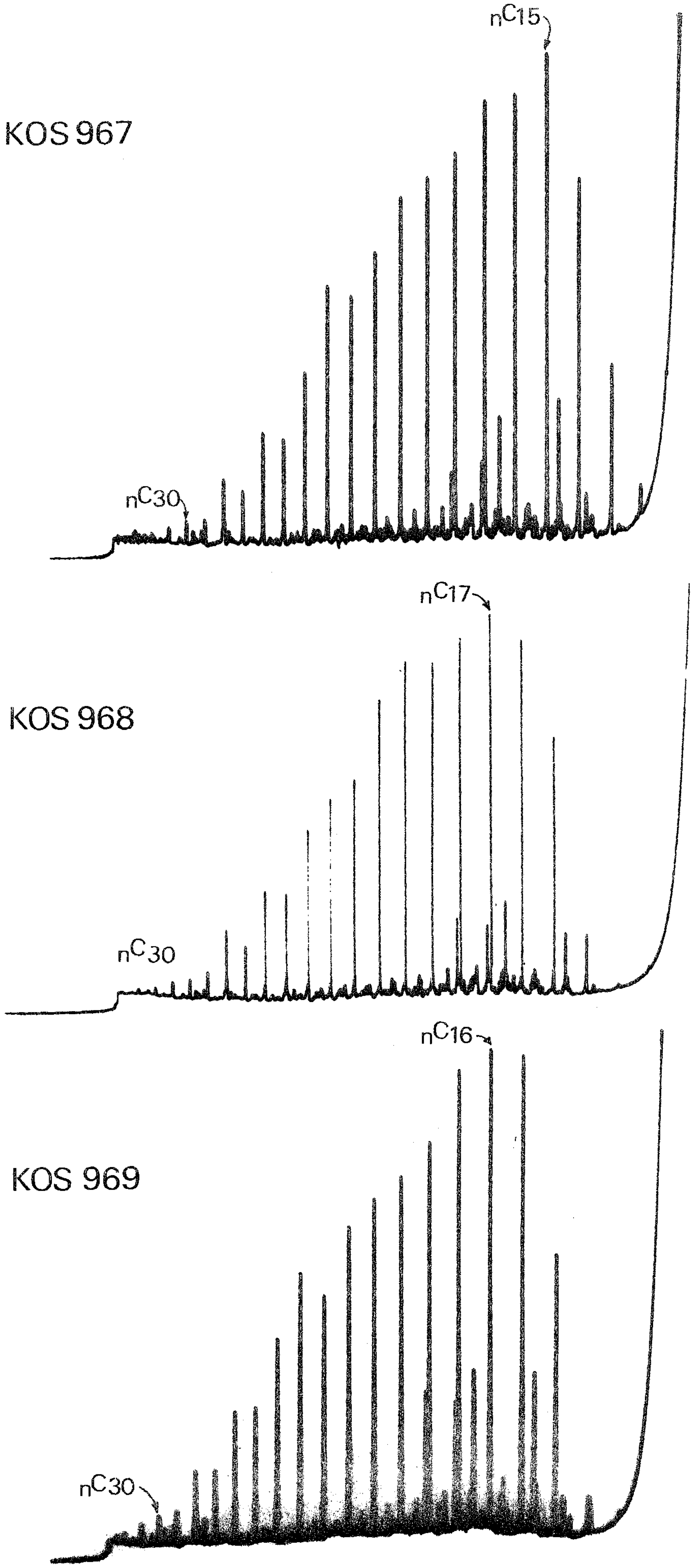
Shale oils: saturated (alkane) hydrocarbon fractions



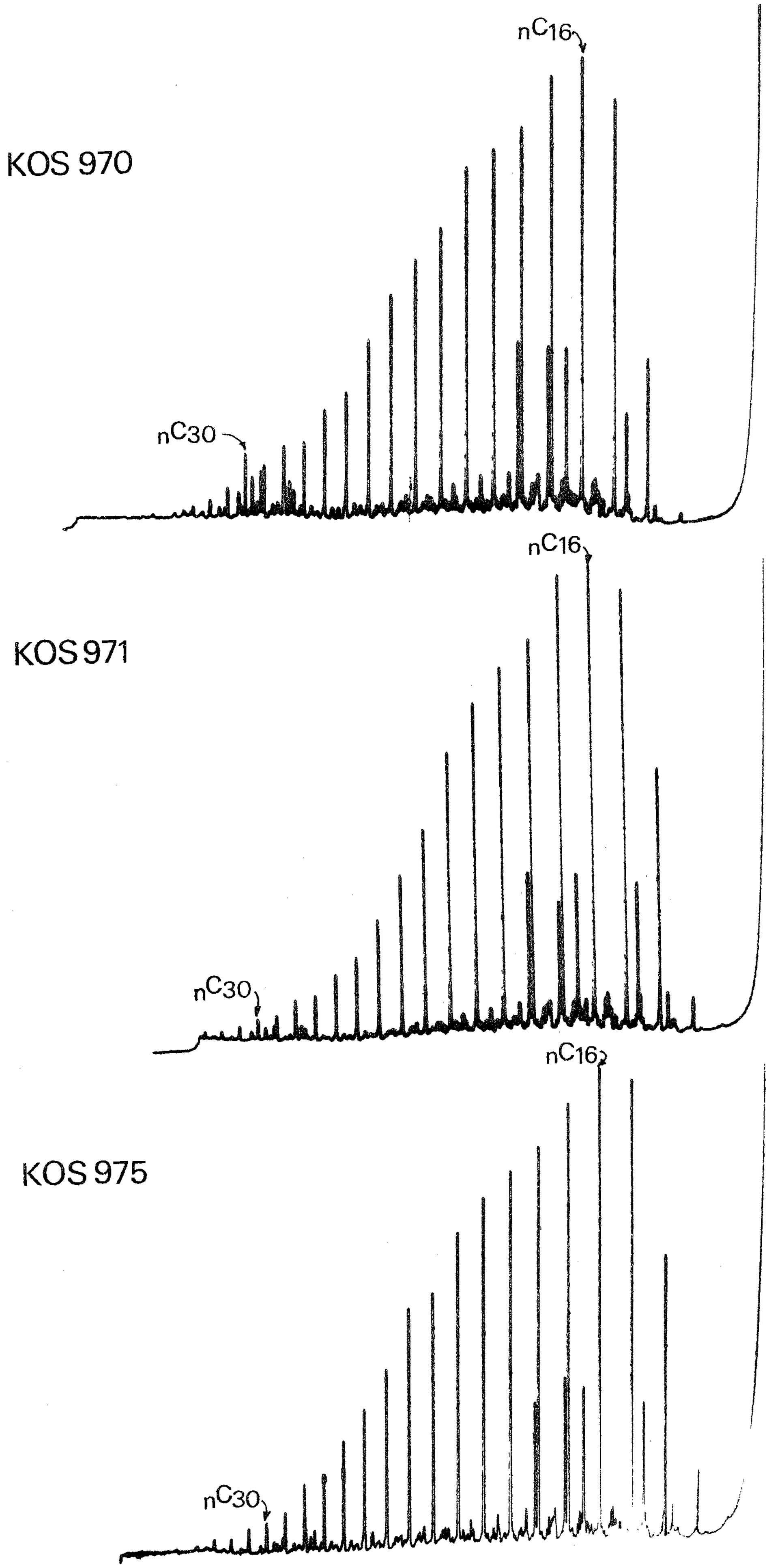
Shale oils: saturated (alkane) hydrocarbon fractions



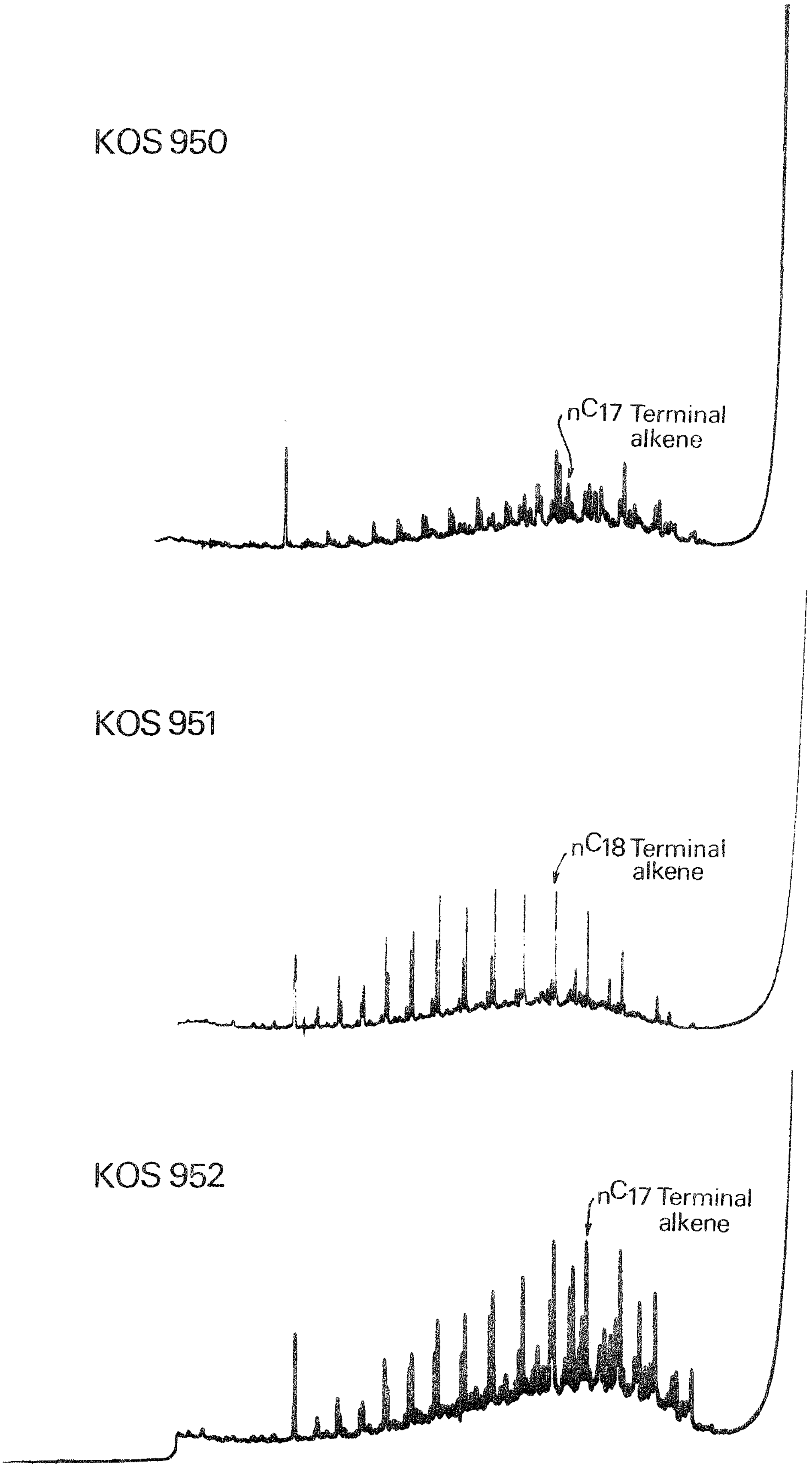
Shale oils: saturated (alkane) hydrocarbon fractions



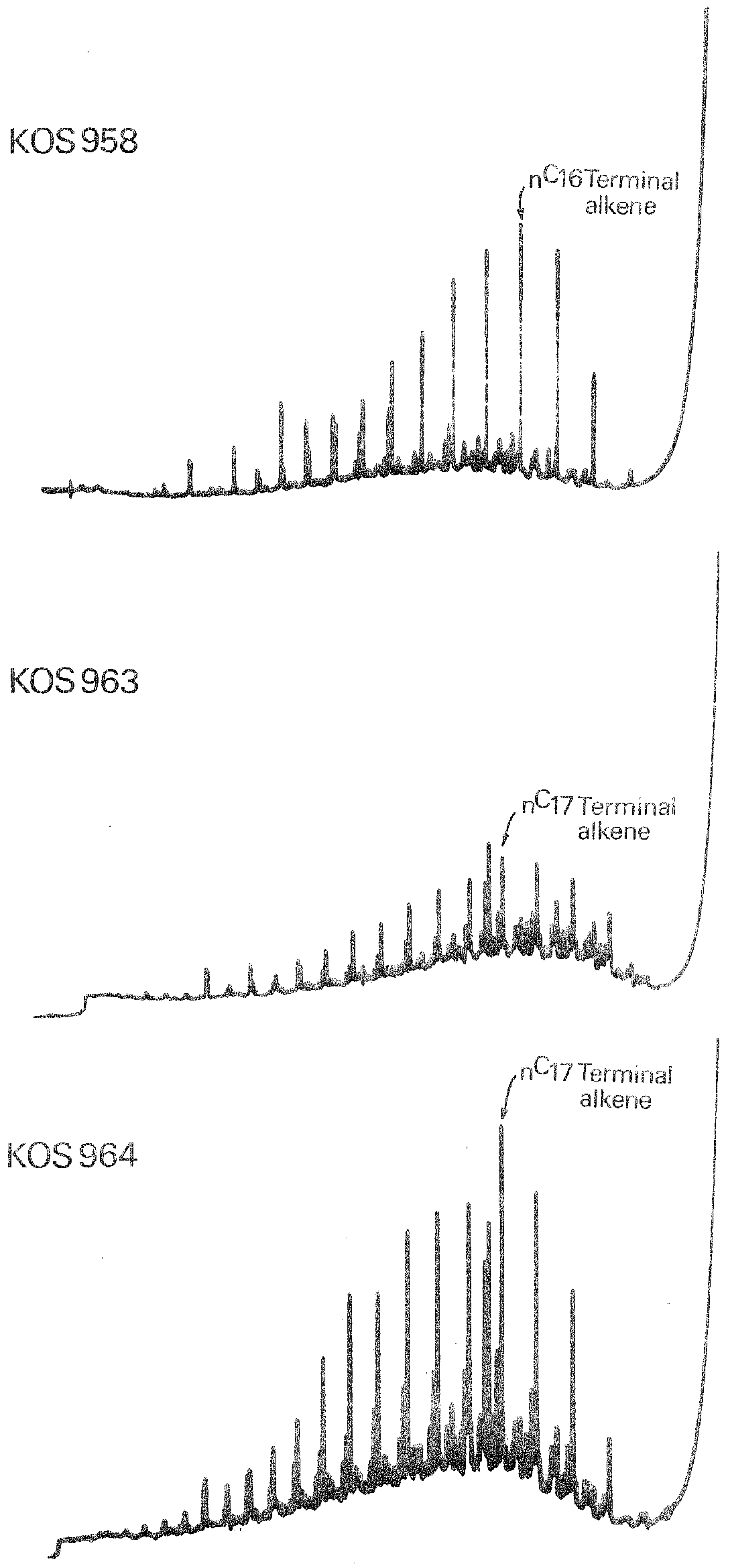
Shale oils: saturated (alkane) hydrocarbon fractions



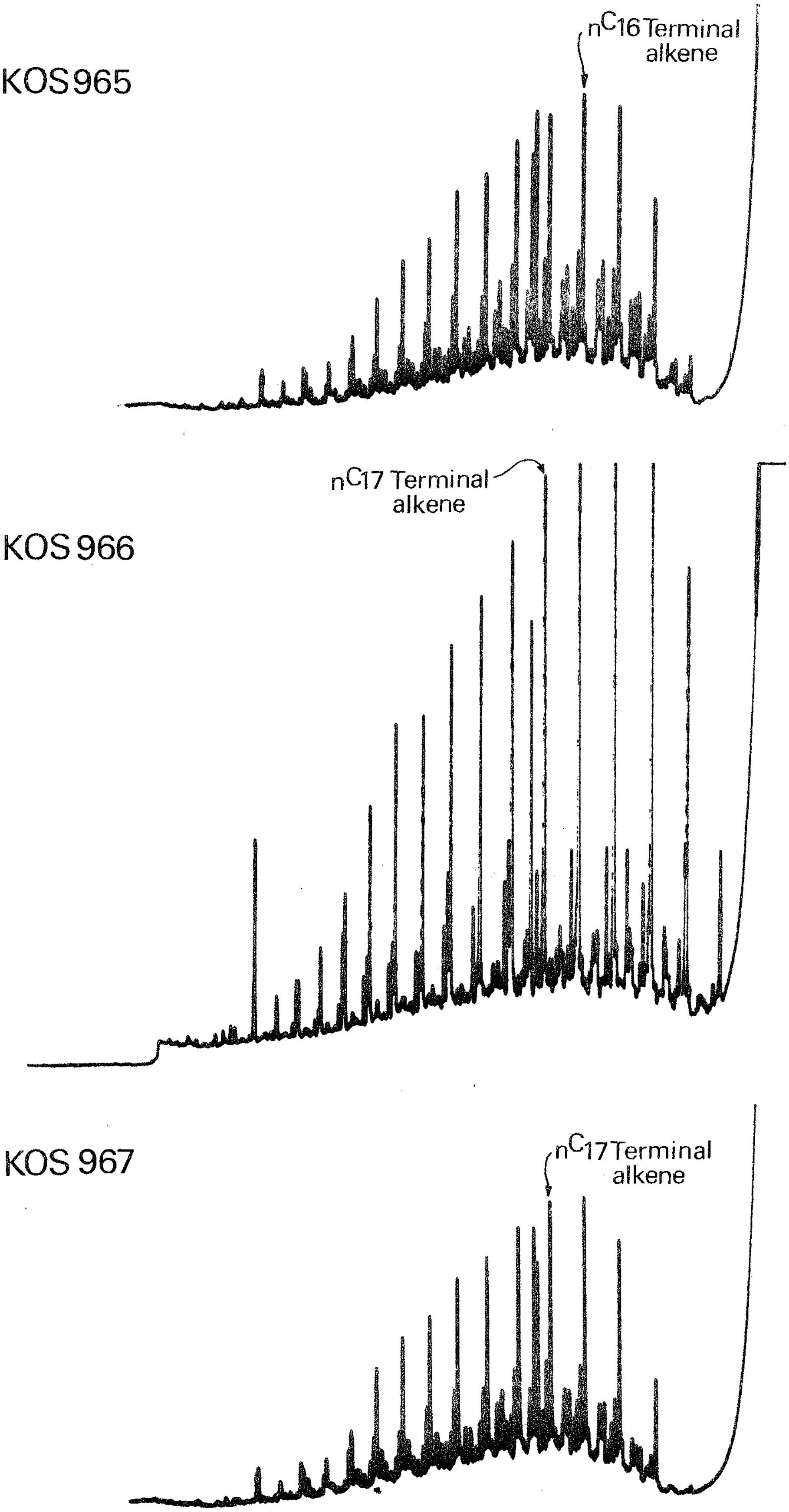
Shale oils: saturated (alkane) hydrocarbon fractions



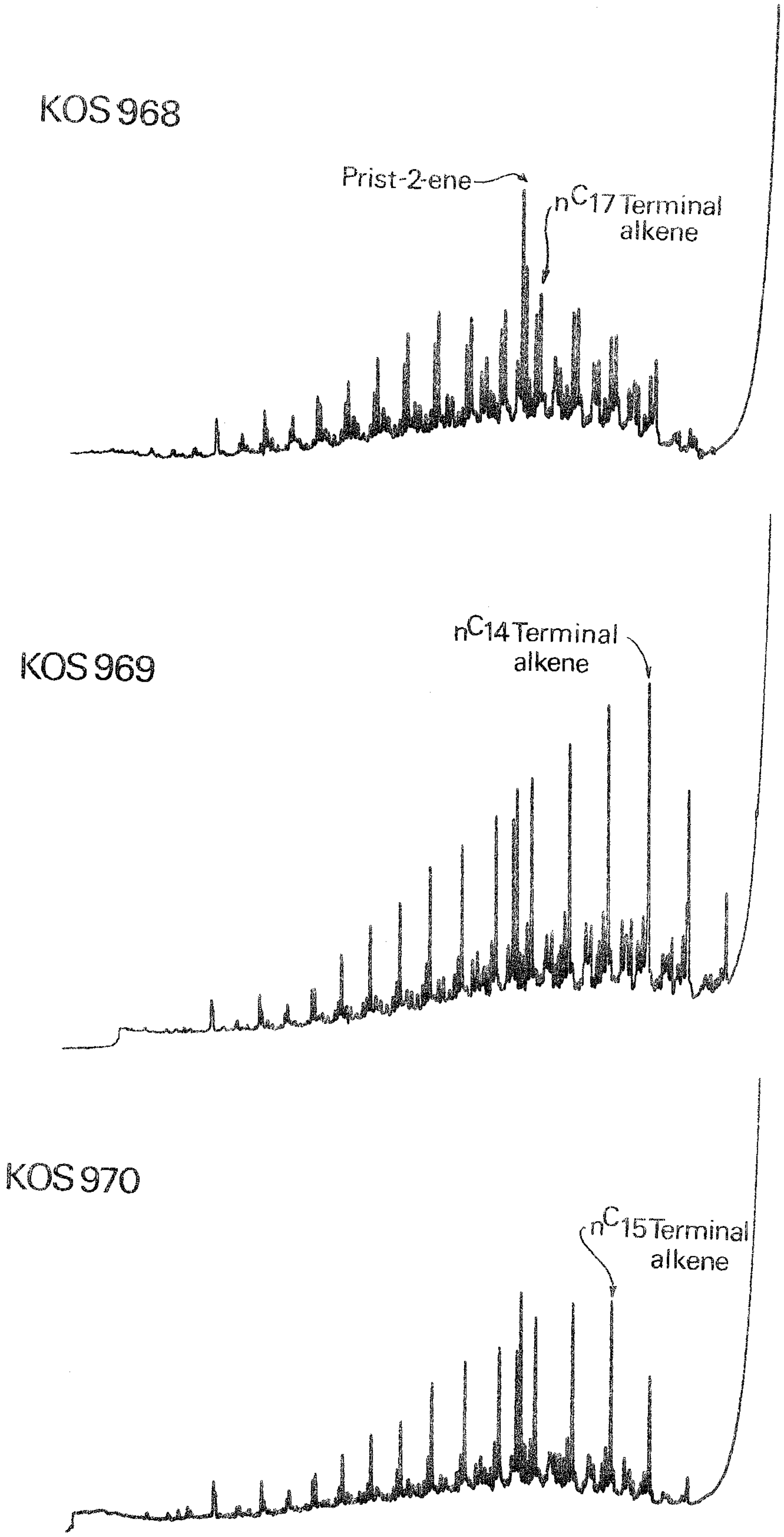
Shale oils: unsaturated (alkene) hydrocarbon fractions



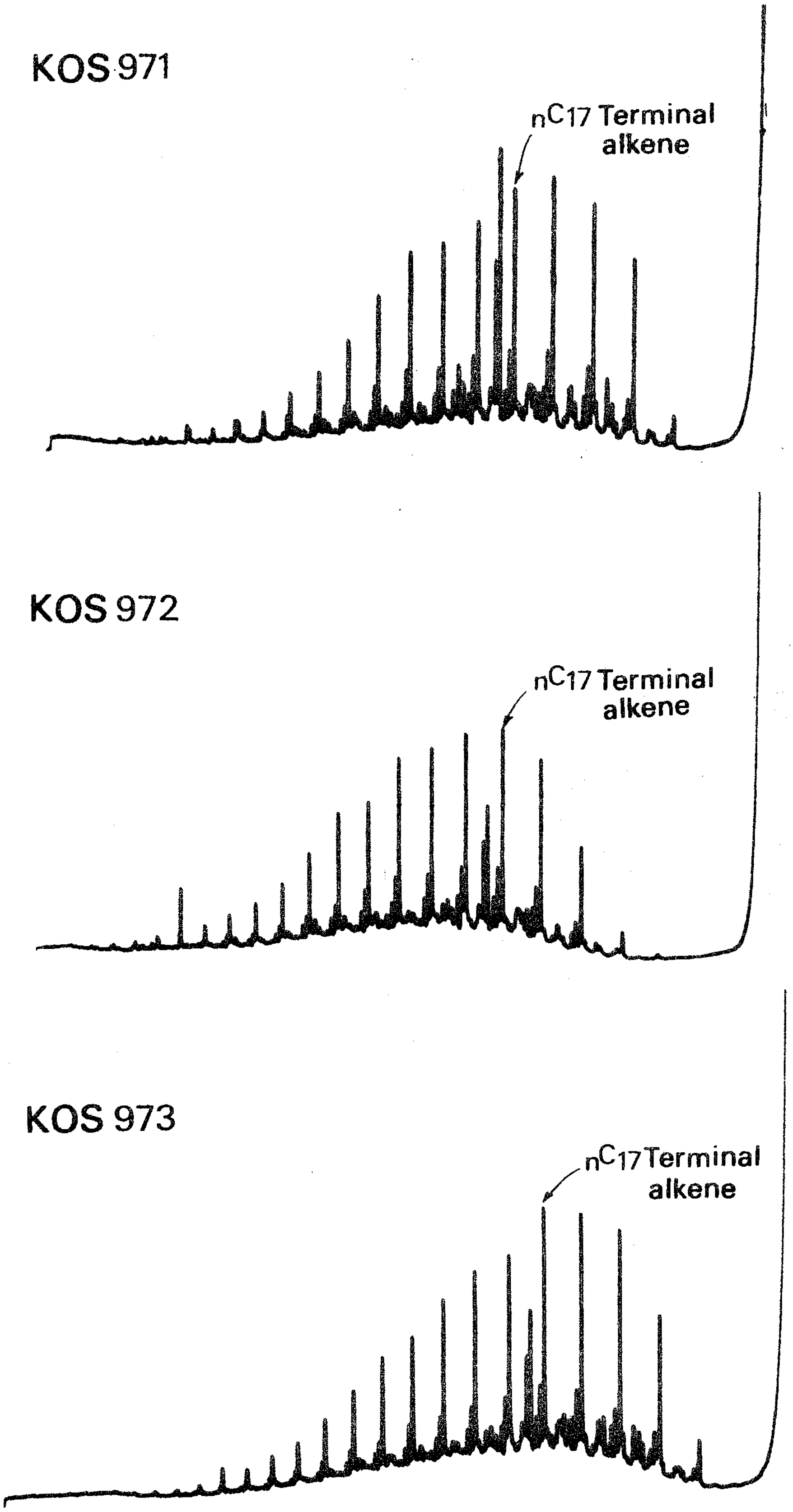
Shale oils: unsaturated (alkene) hydrocarbon fractions



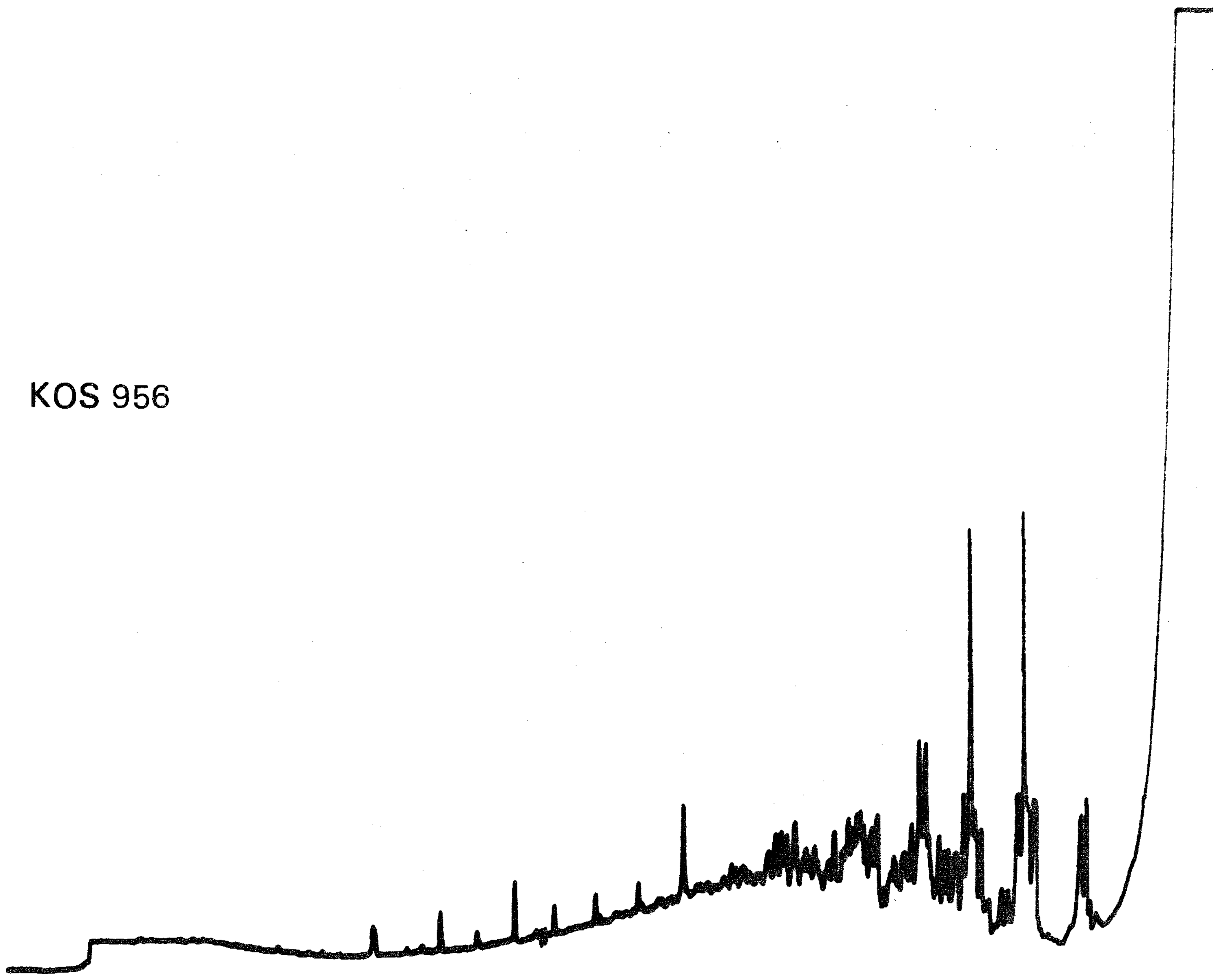
Shale oils: unsaturated (alkene) hydrocarbon fractions



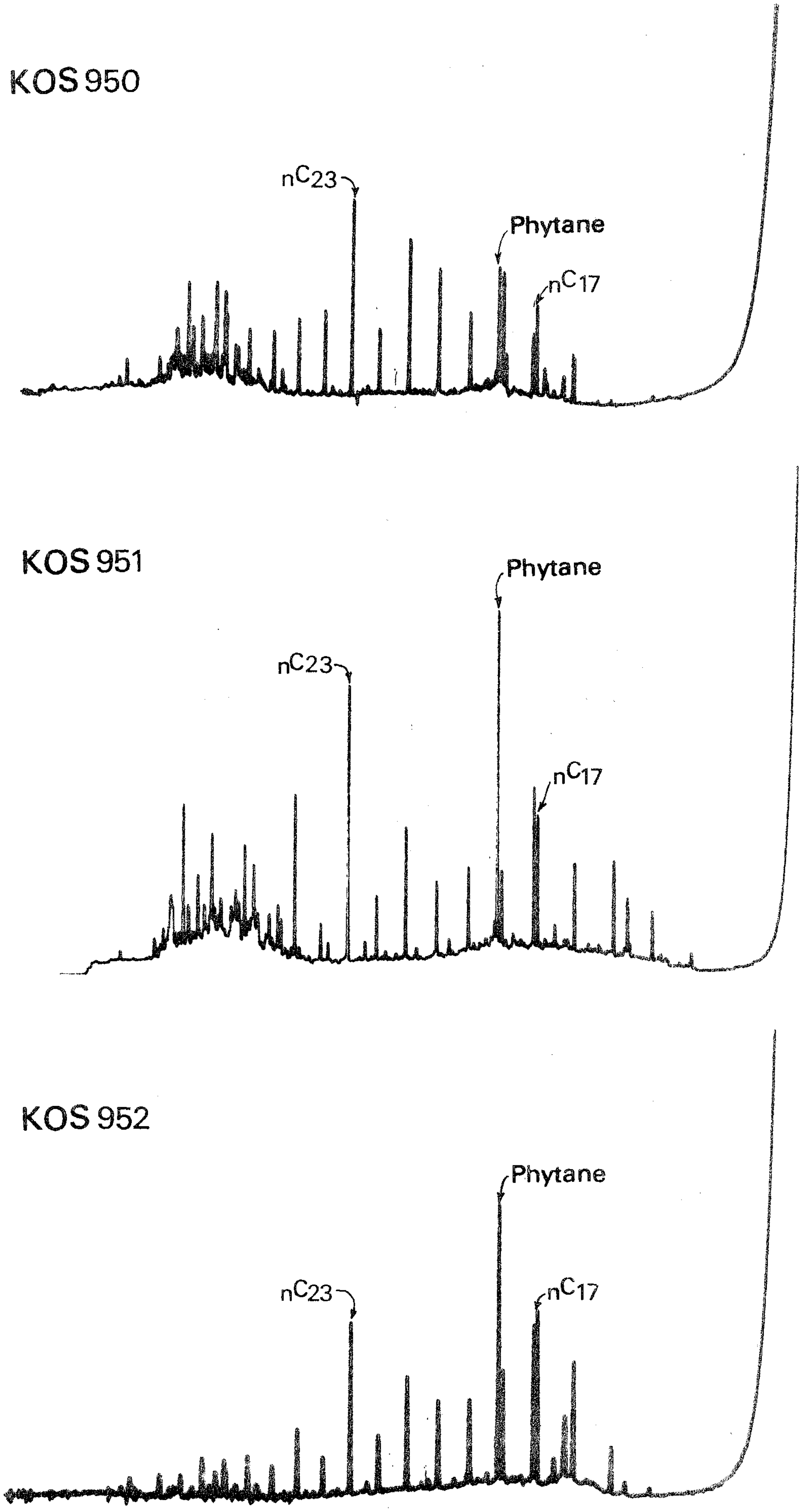
Shale oils: unsaturated (alkene) hydrocarbon fractions



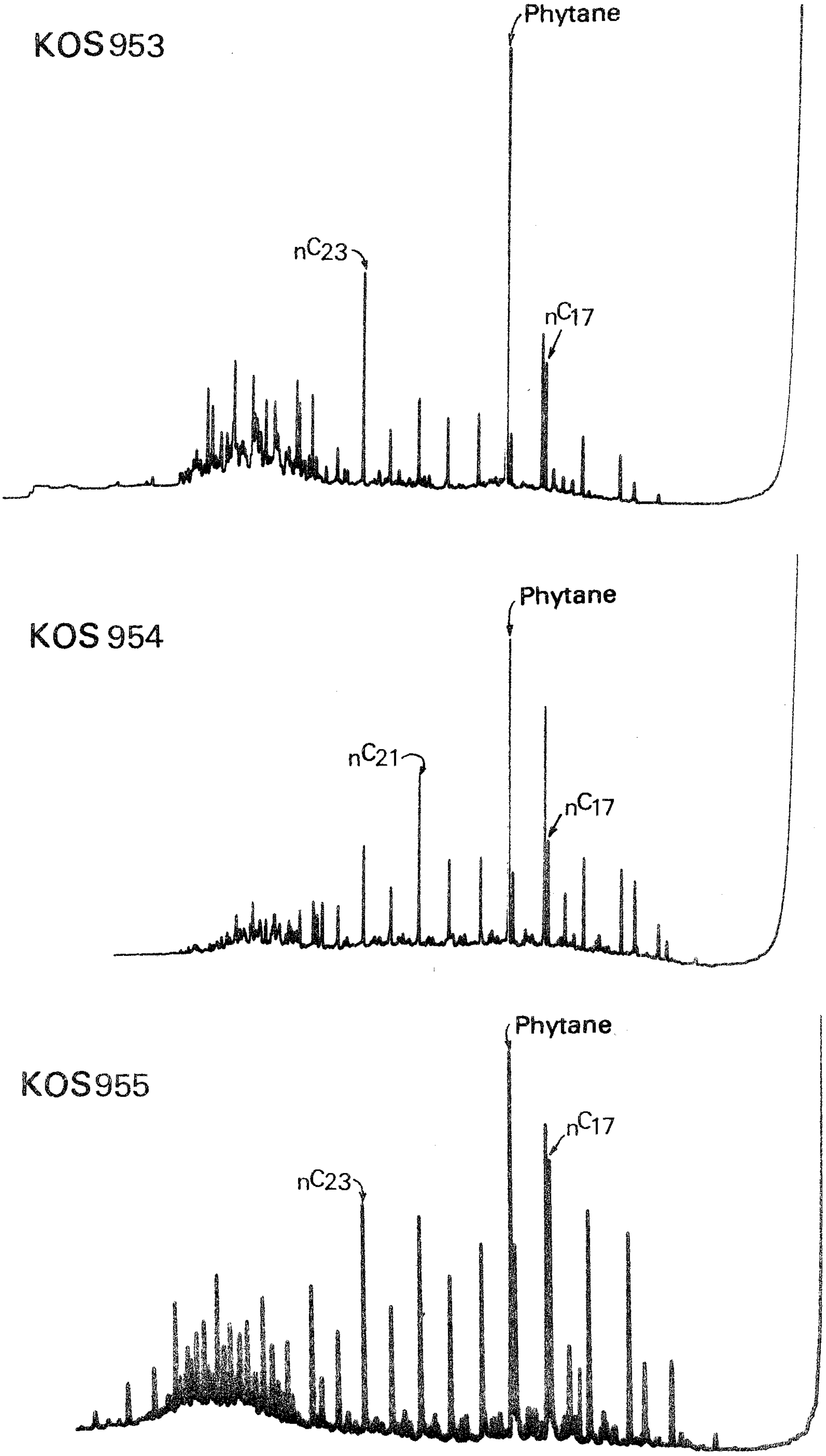
Shale oils: unsaturated (alkene) hydrocarbon fractions



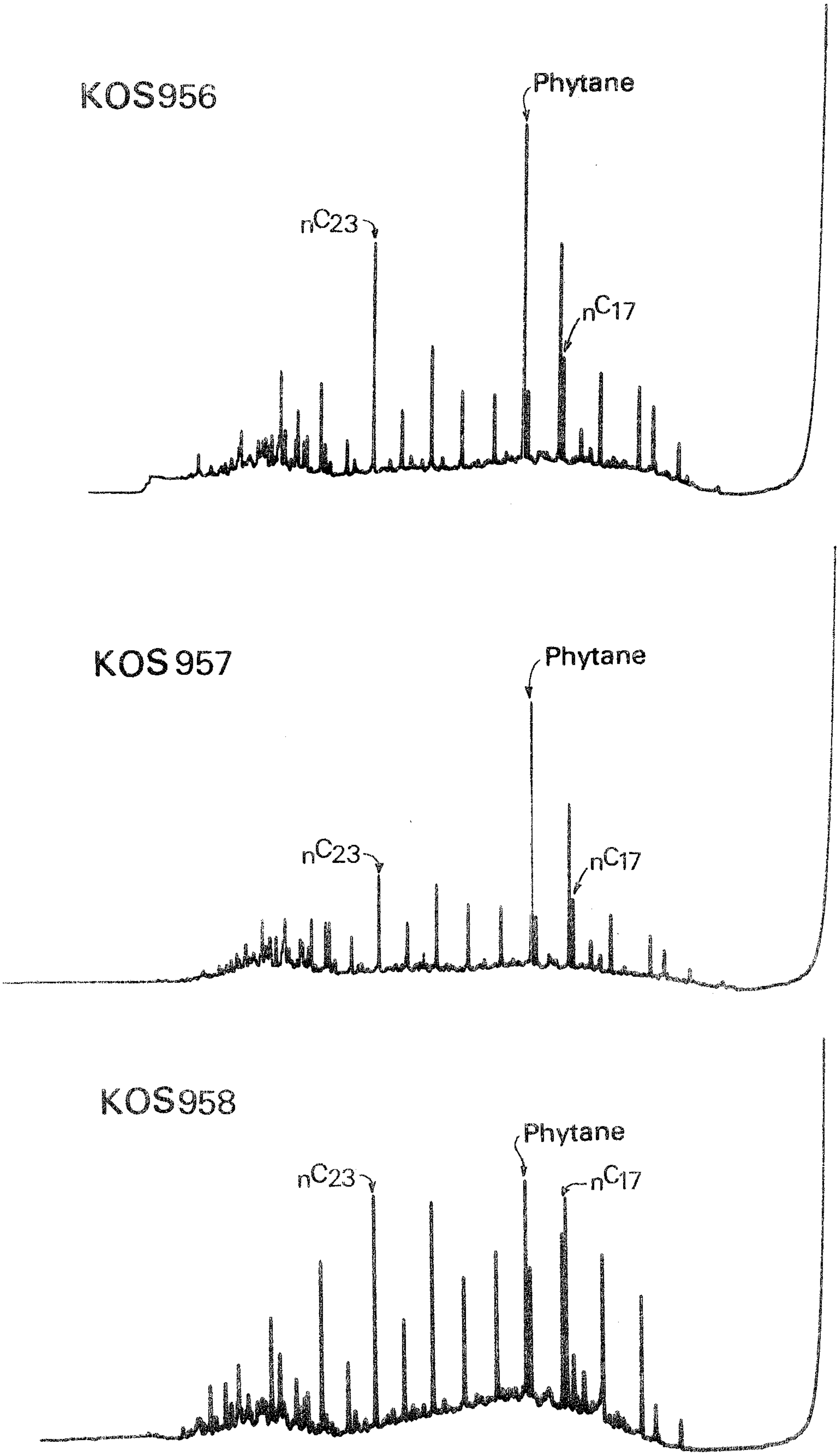
Shale oil: aromatic fraction



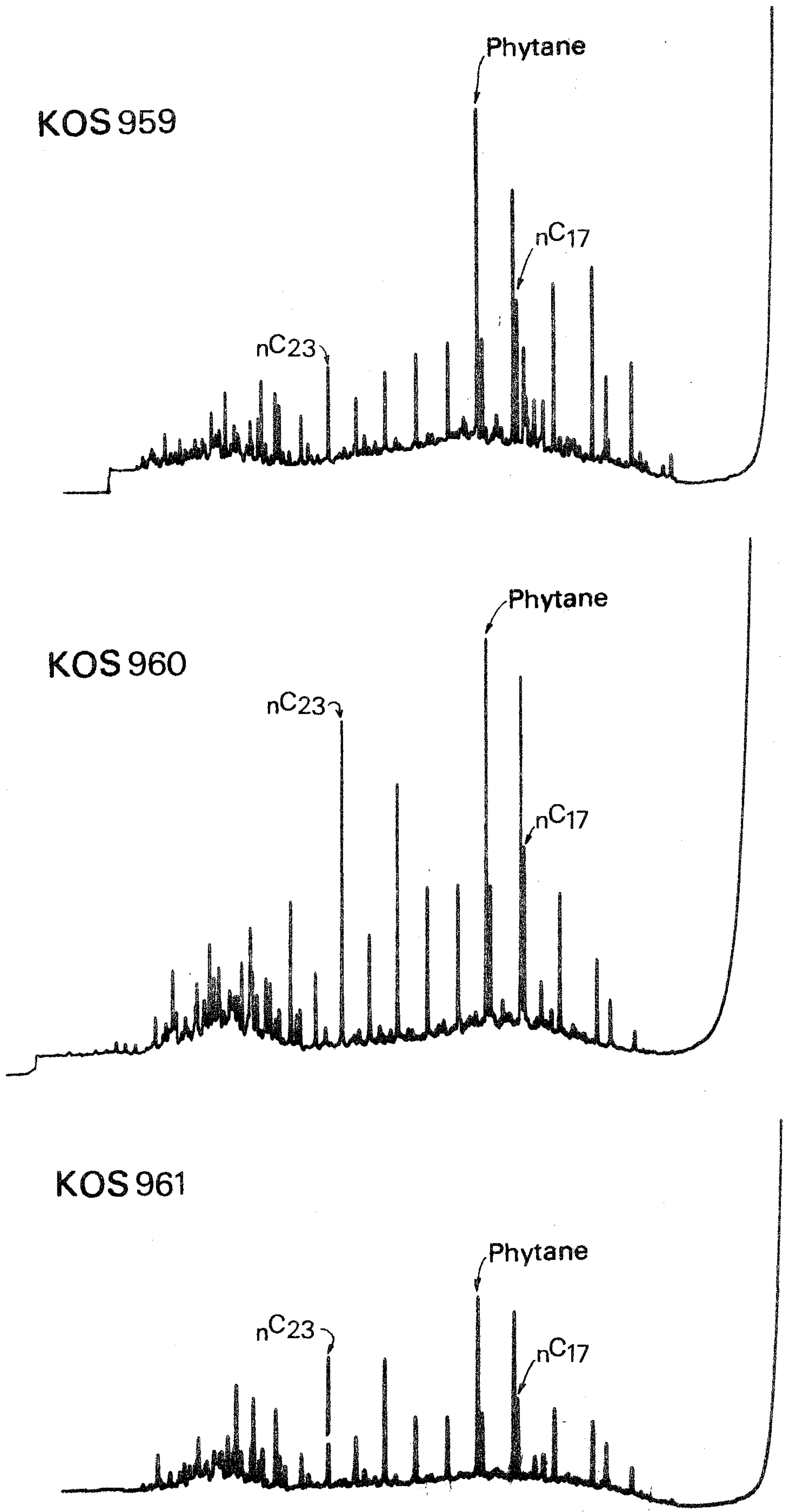
Bitumens: saturated (alkane) hydrocarbon fractions



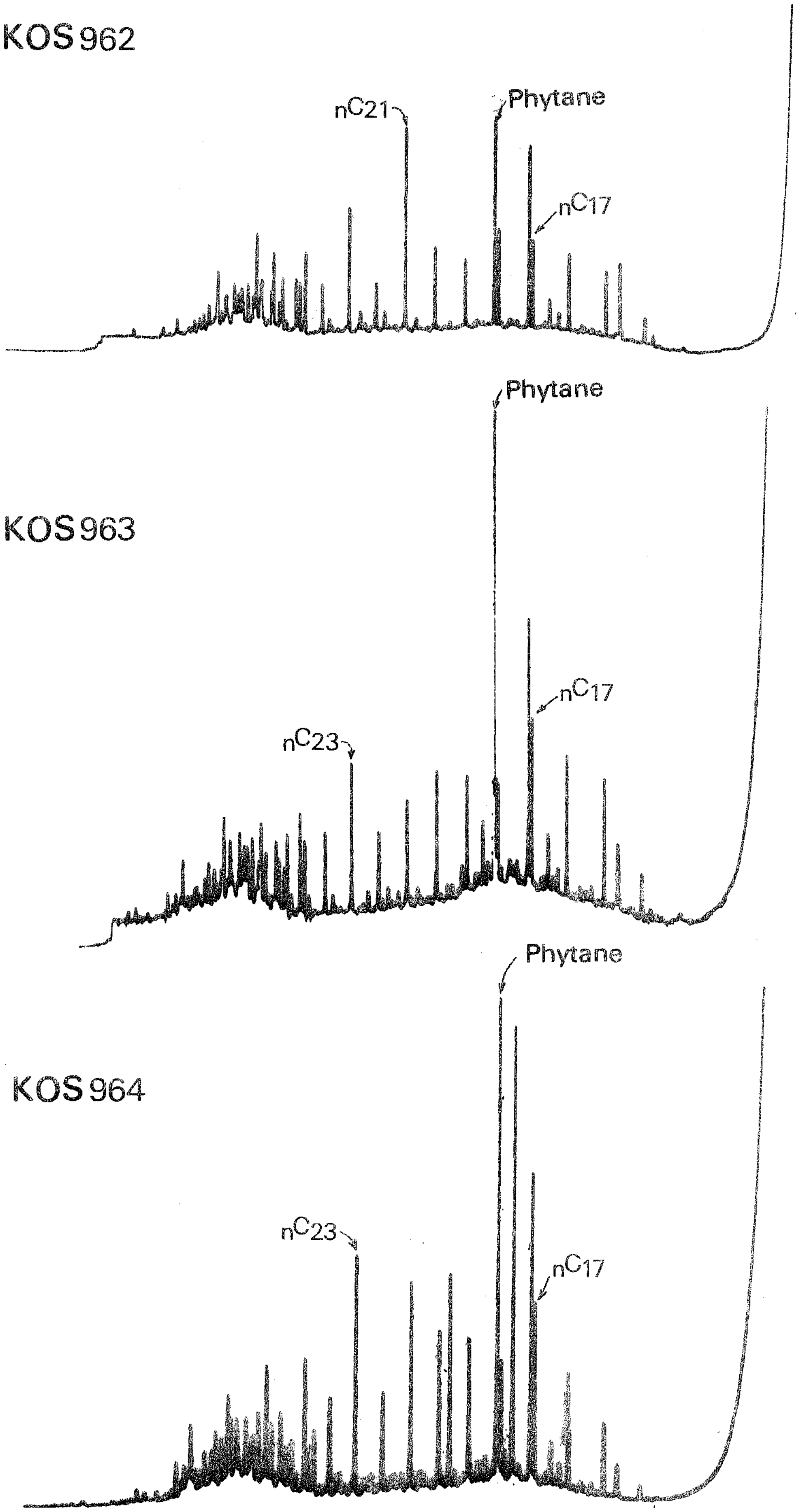
Bitumens: saturated (alkane) hydrocarbon fractions



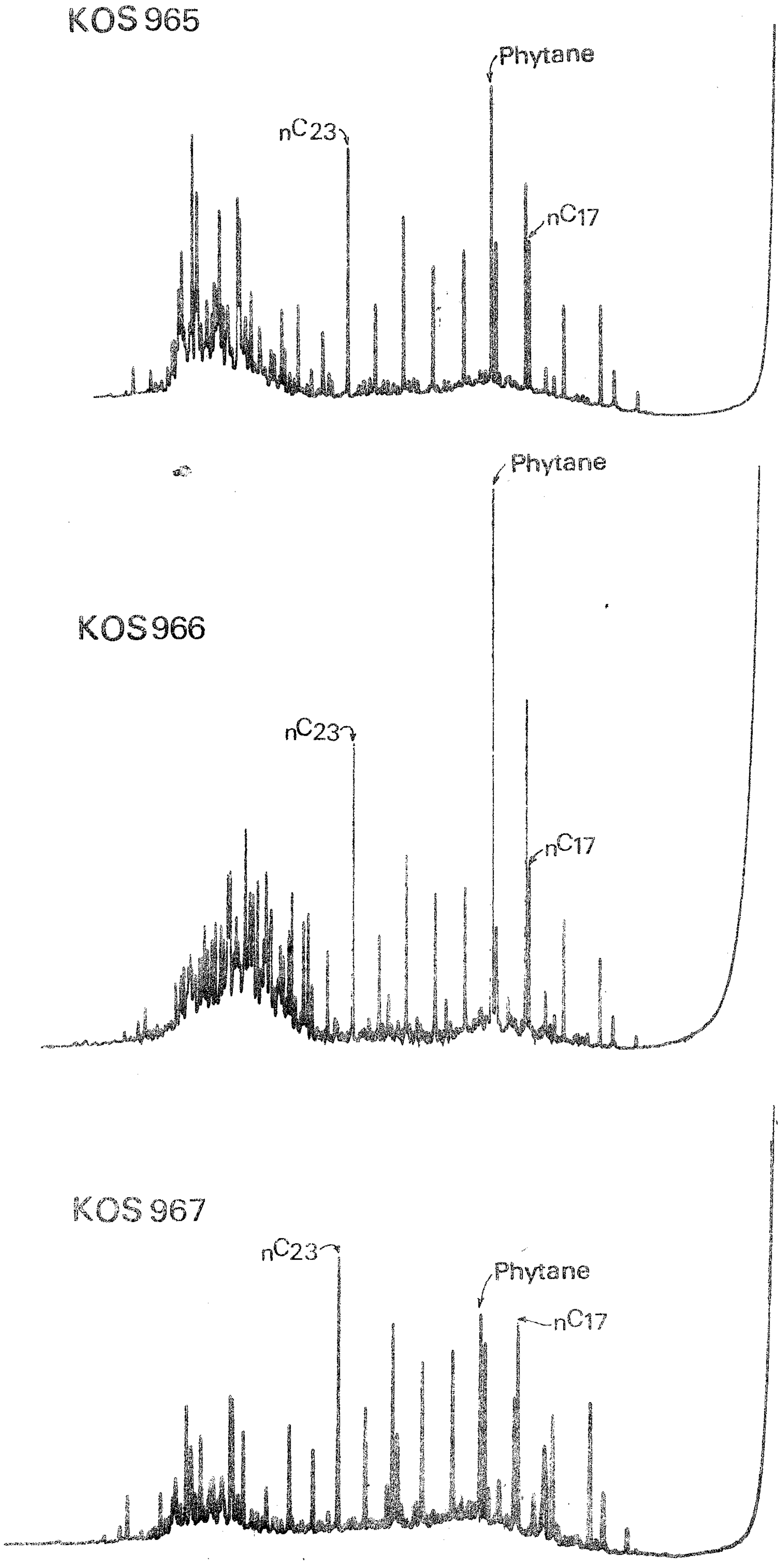
Bitumens: saturated (alkane) hydrocarbon fractions



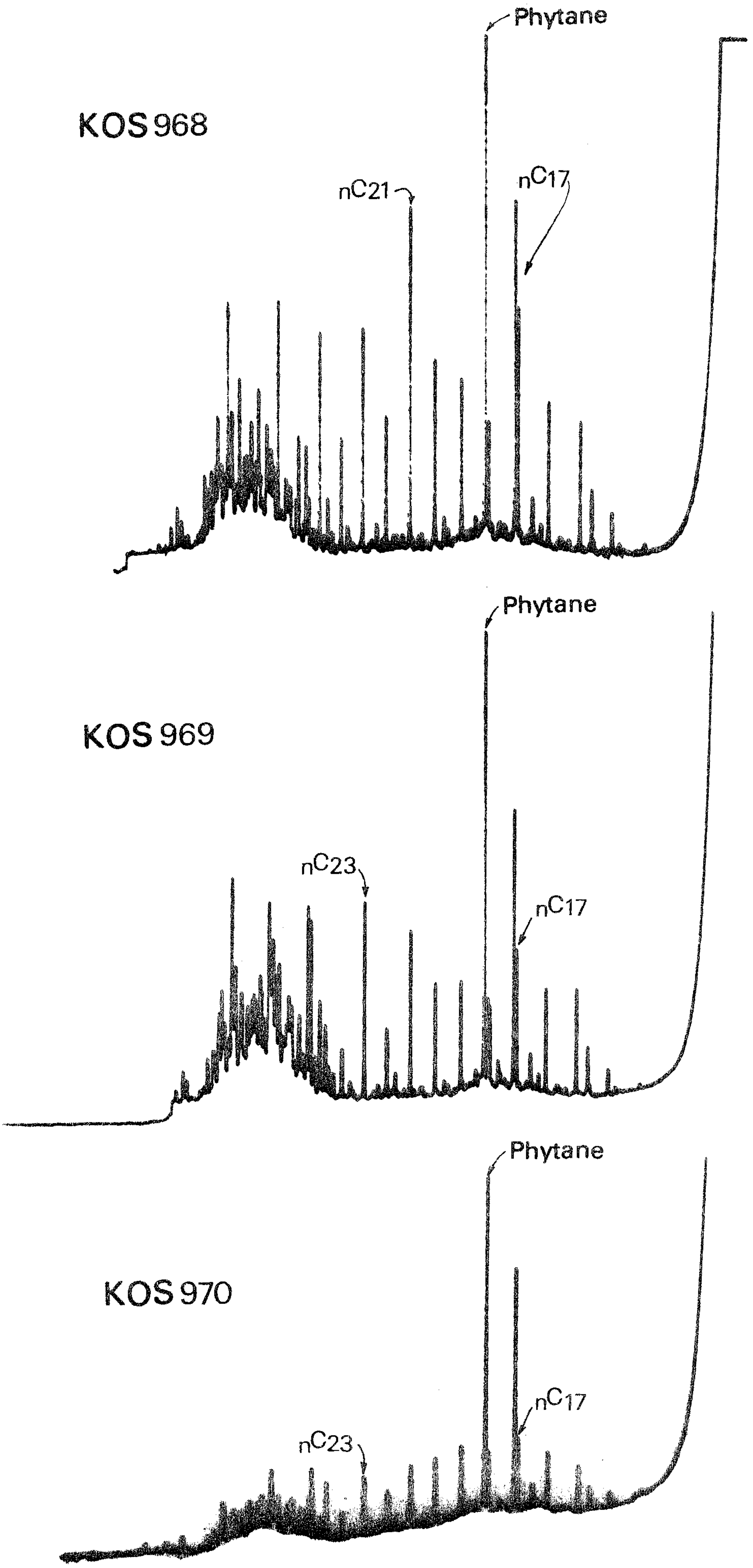
Bitumens: saturated (alkane) hydrocarbon fractions



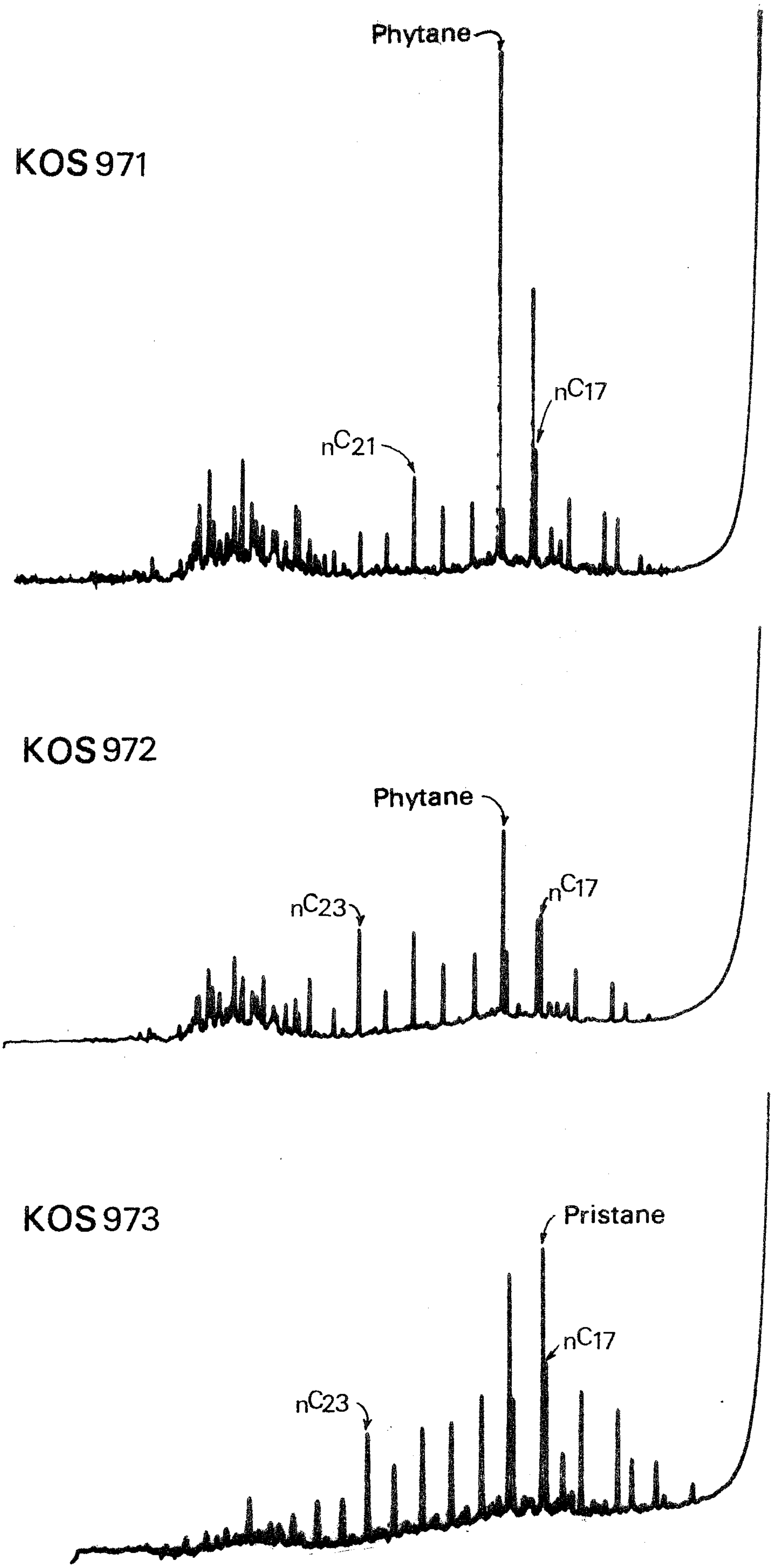
Bitumens: saturated (alkane) hydrocarbon fractions



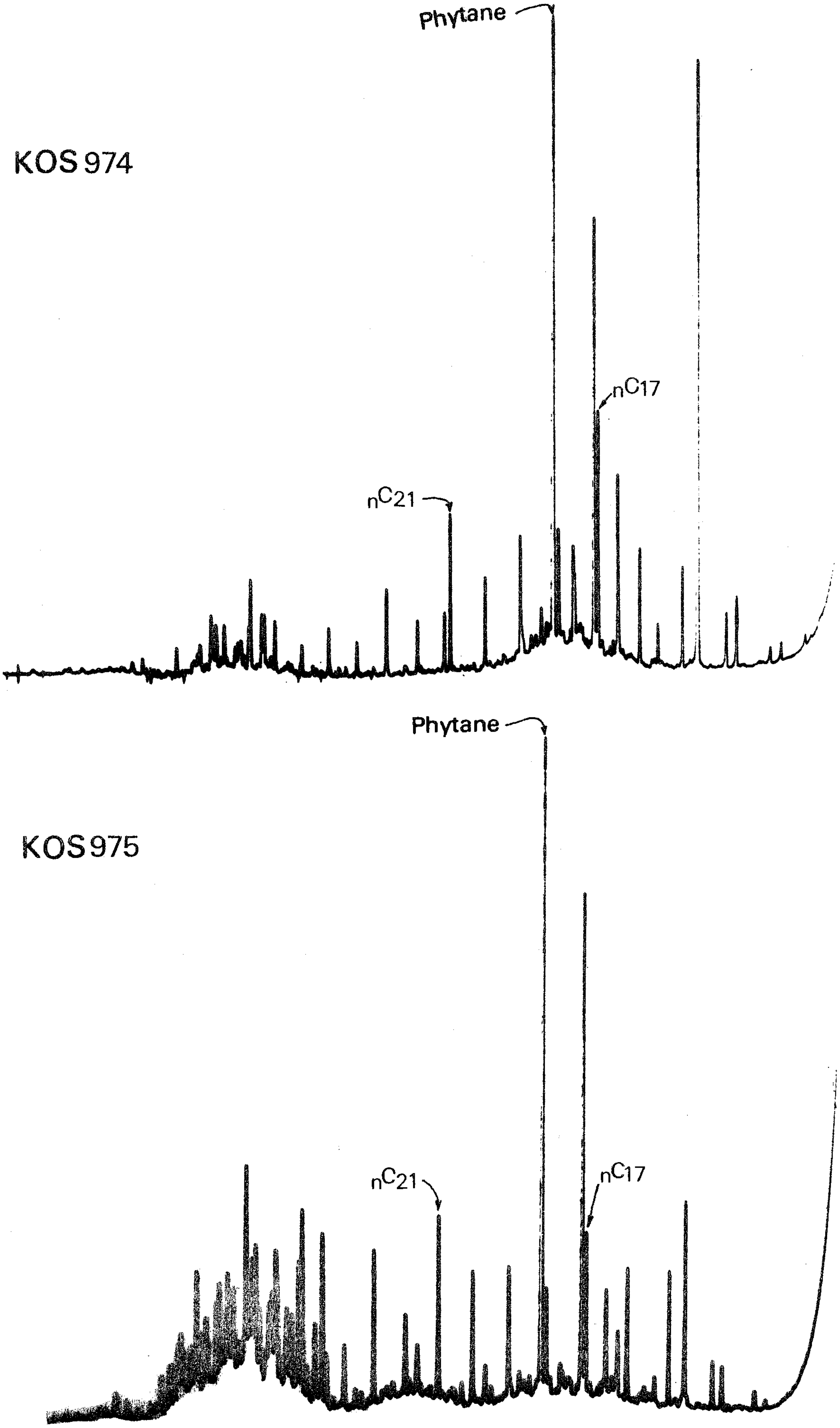
Bitumens: saturated (alkane) hydrocarbon fractions



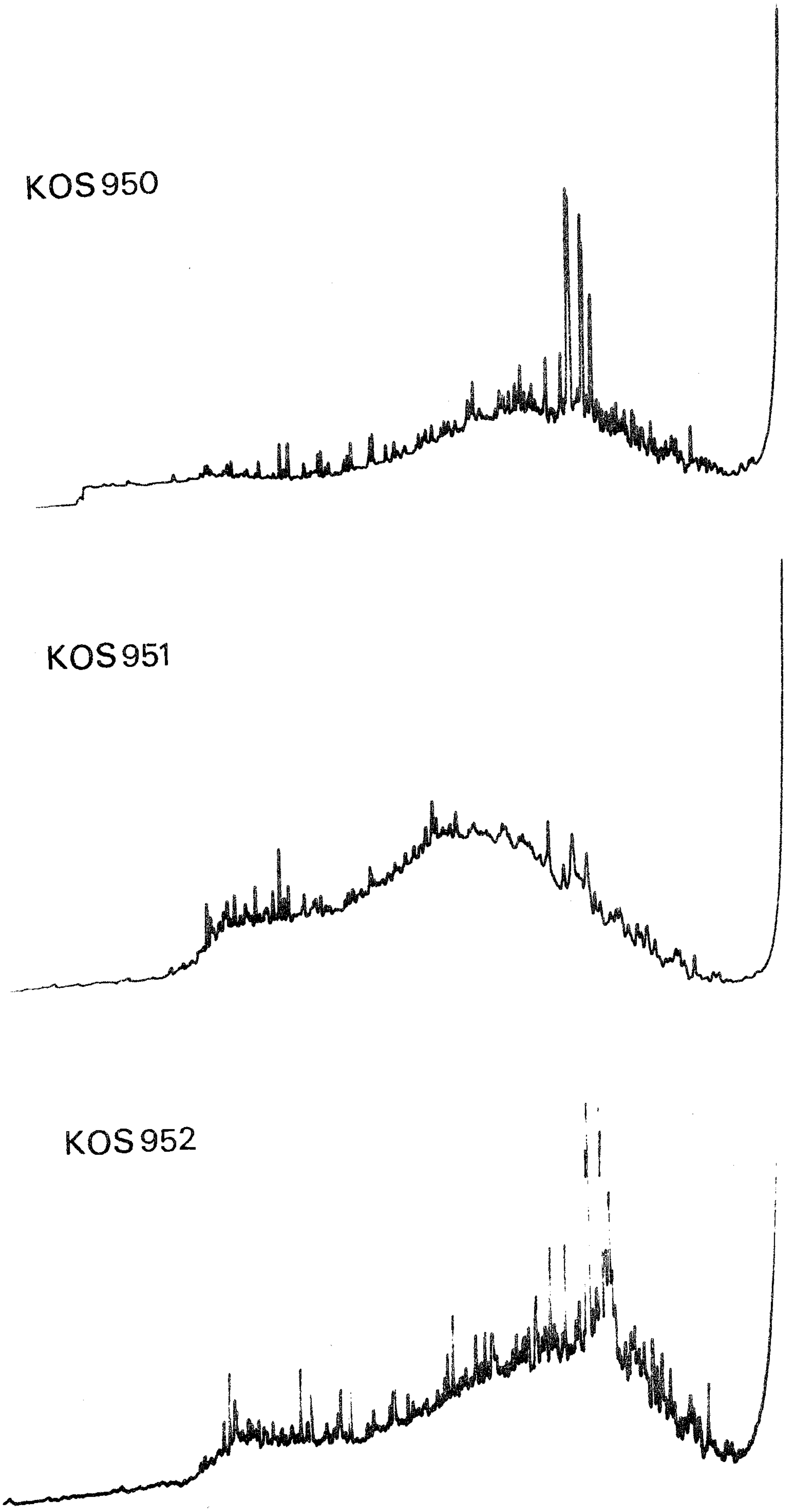
Bitumens: saturated (alkane) hydrocarbon fractions



Bitumens: saturated (alkane) hydrocarbon fractions



Bitumens: saturated (alkane) hydrocarbon fractions

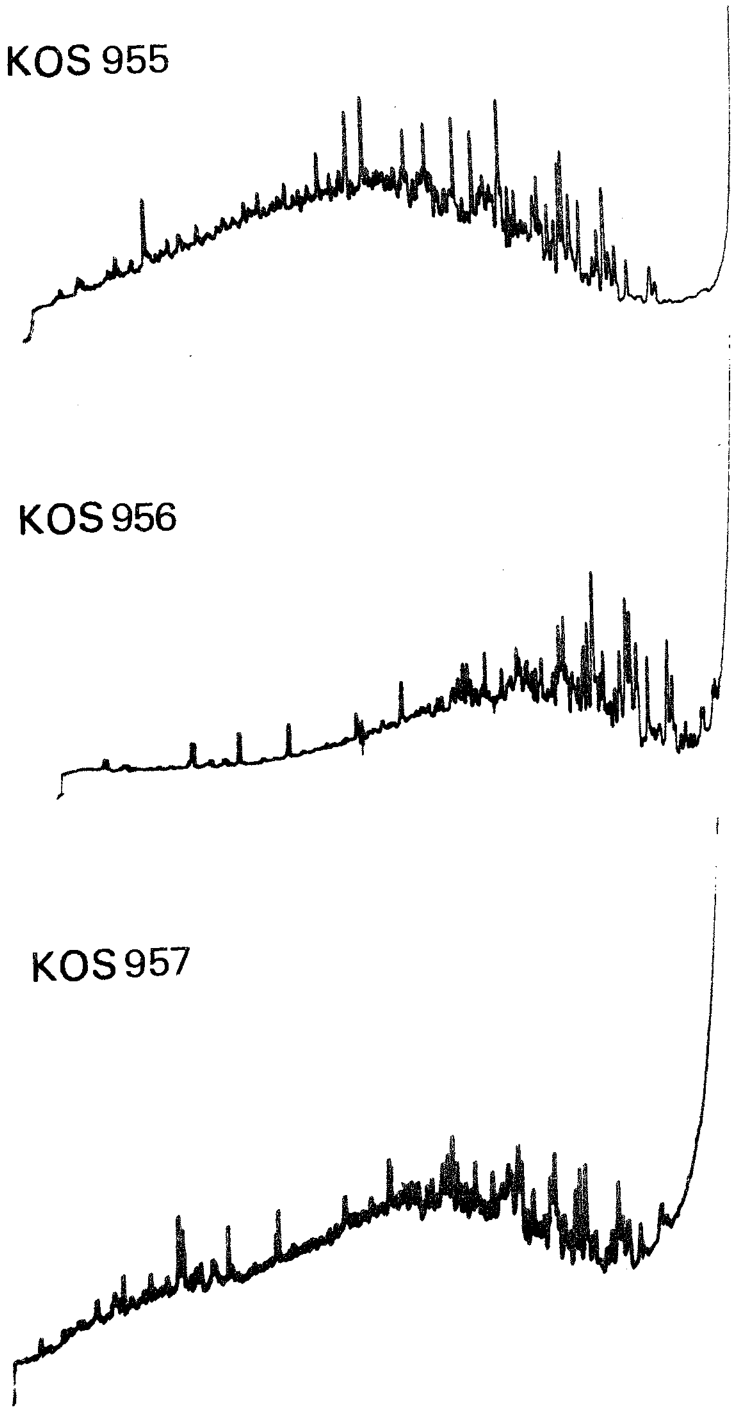


KOS 950

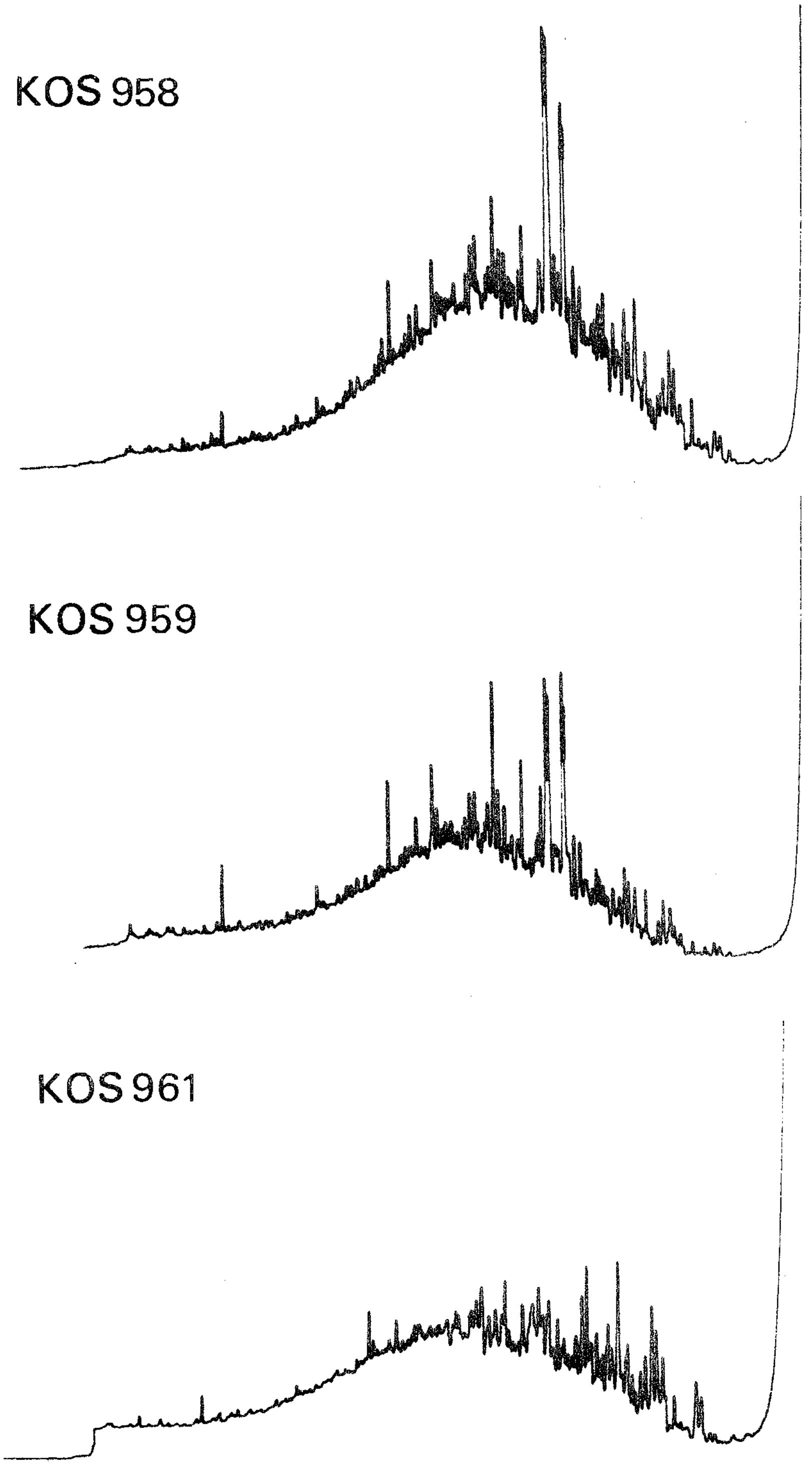
KOS 951

KOS 952

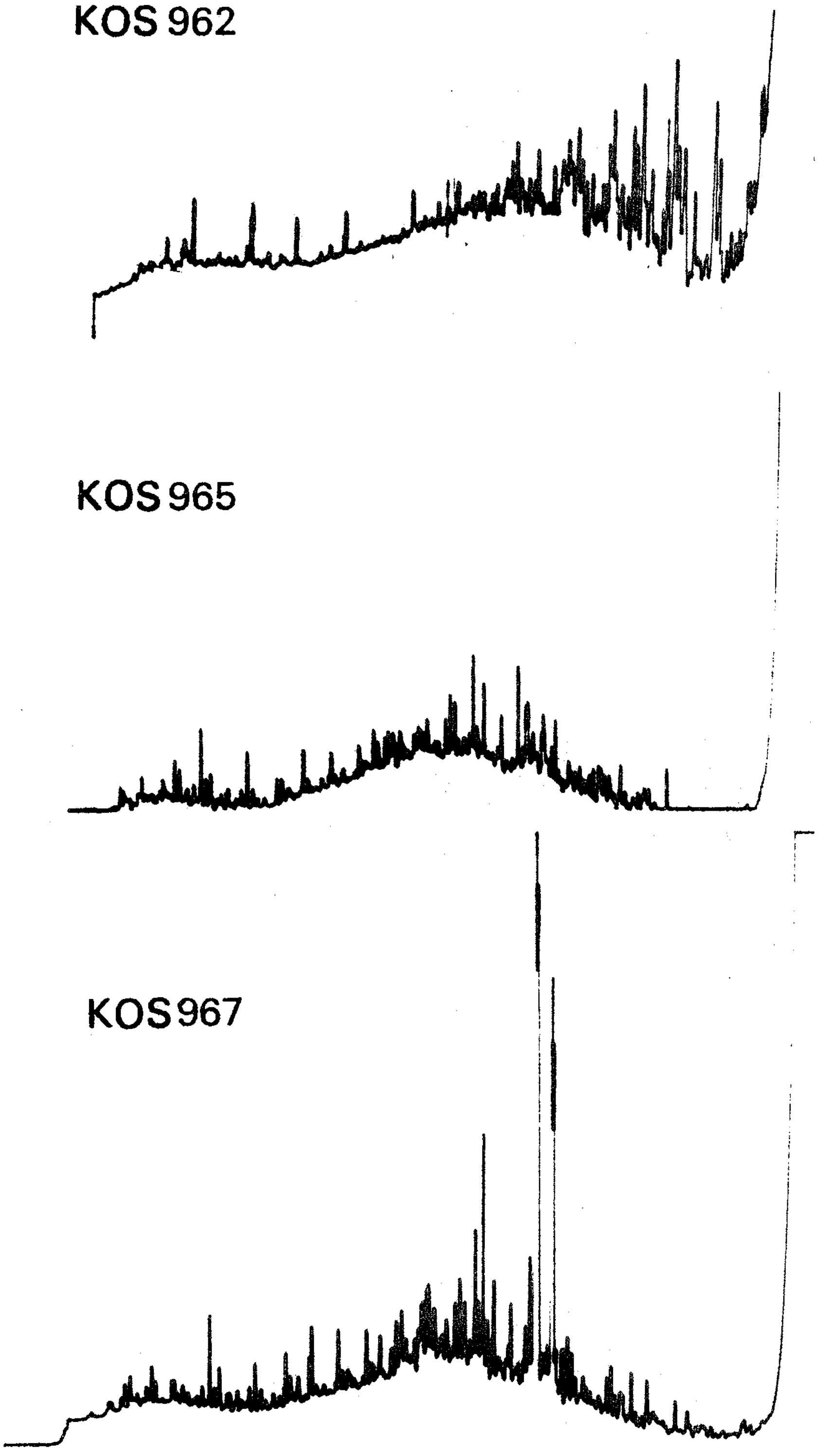
Bitumens: aromatic fractions



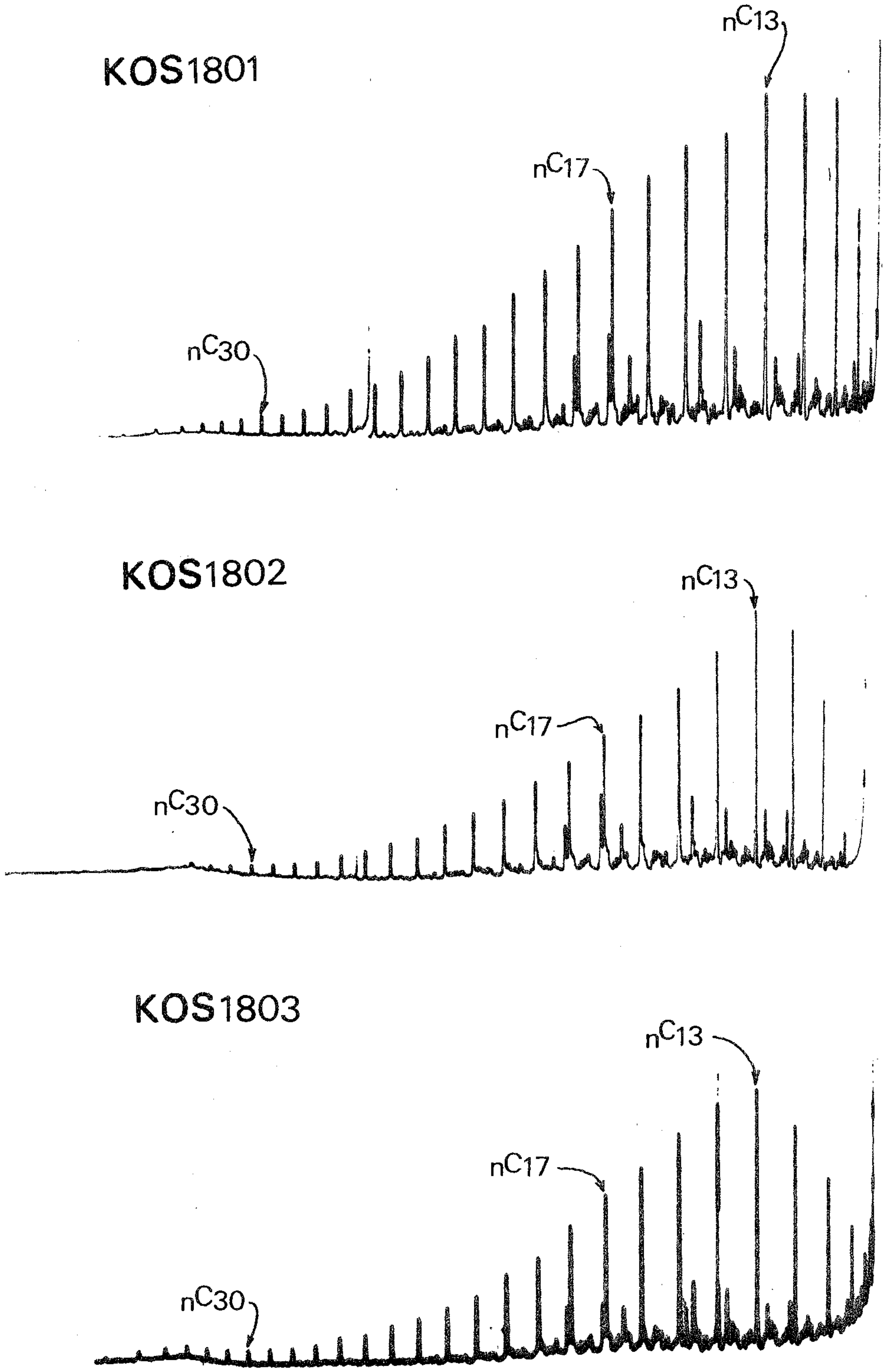
Bitumens: aromatic fractions



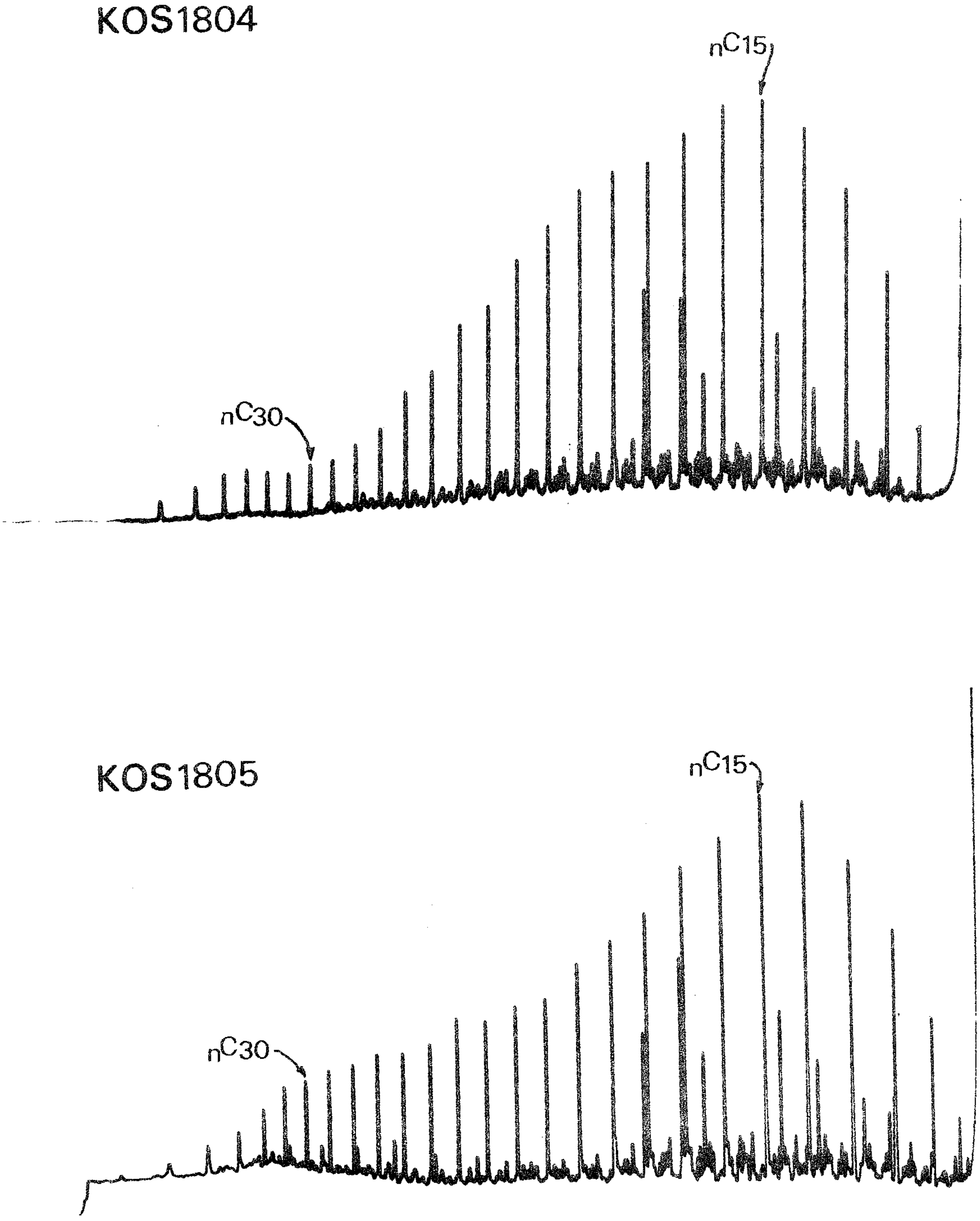
Bitumens: aromatic fractions



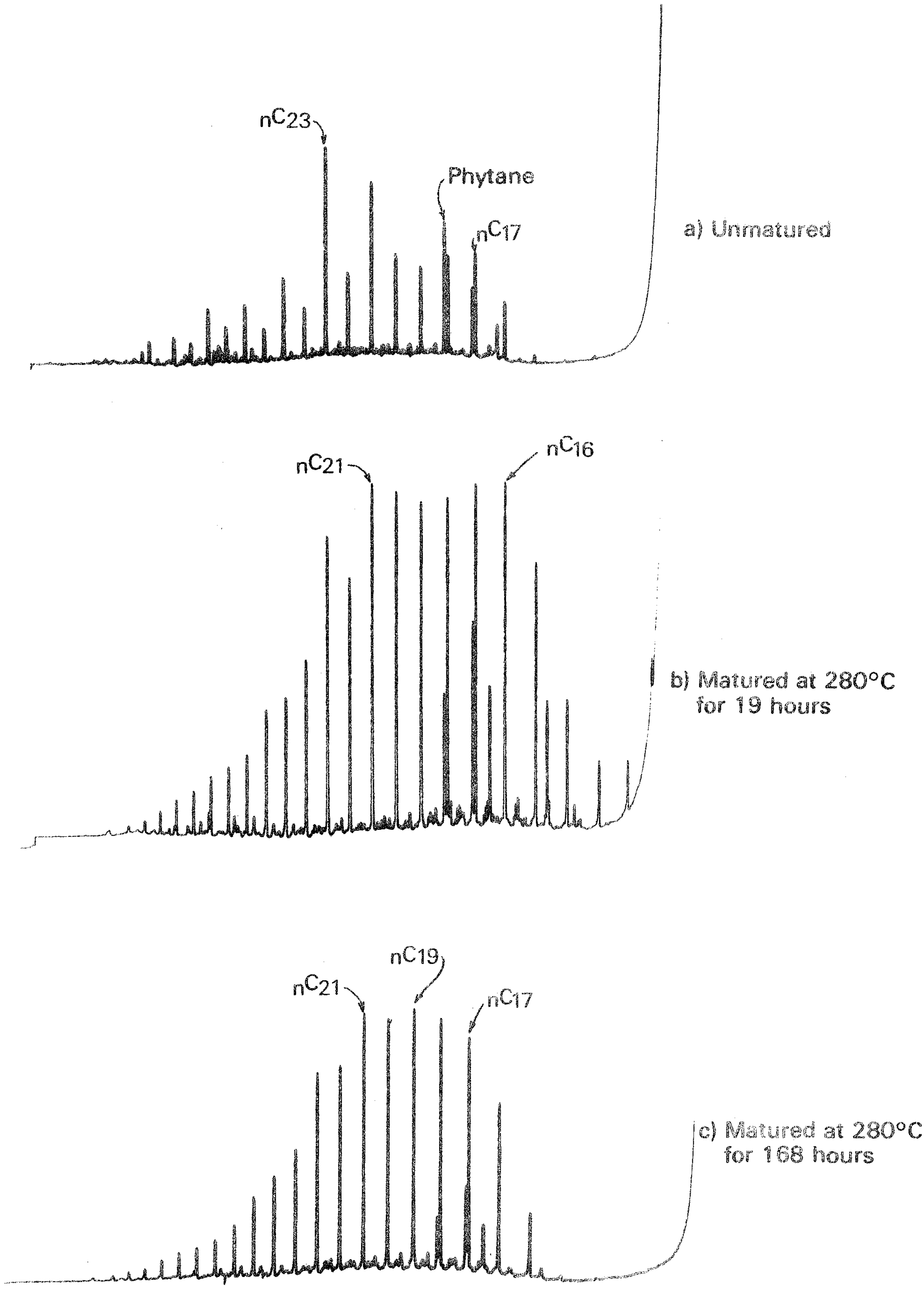
Bitumens: aromatic fractions



North Sea Crude oils: saturated (alkane) hydrocarbon fractions



North Sea Crude oils: saturated (alkane) hydrocarbon fractions

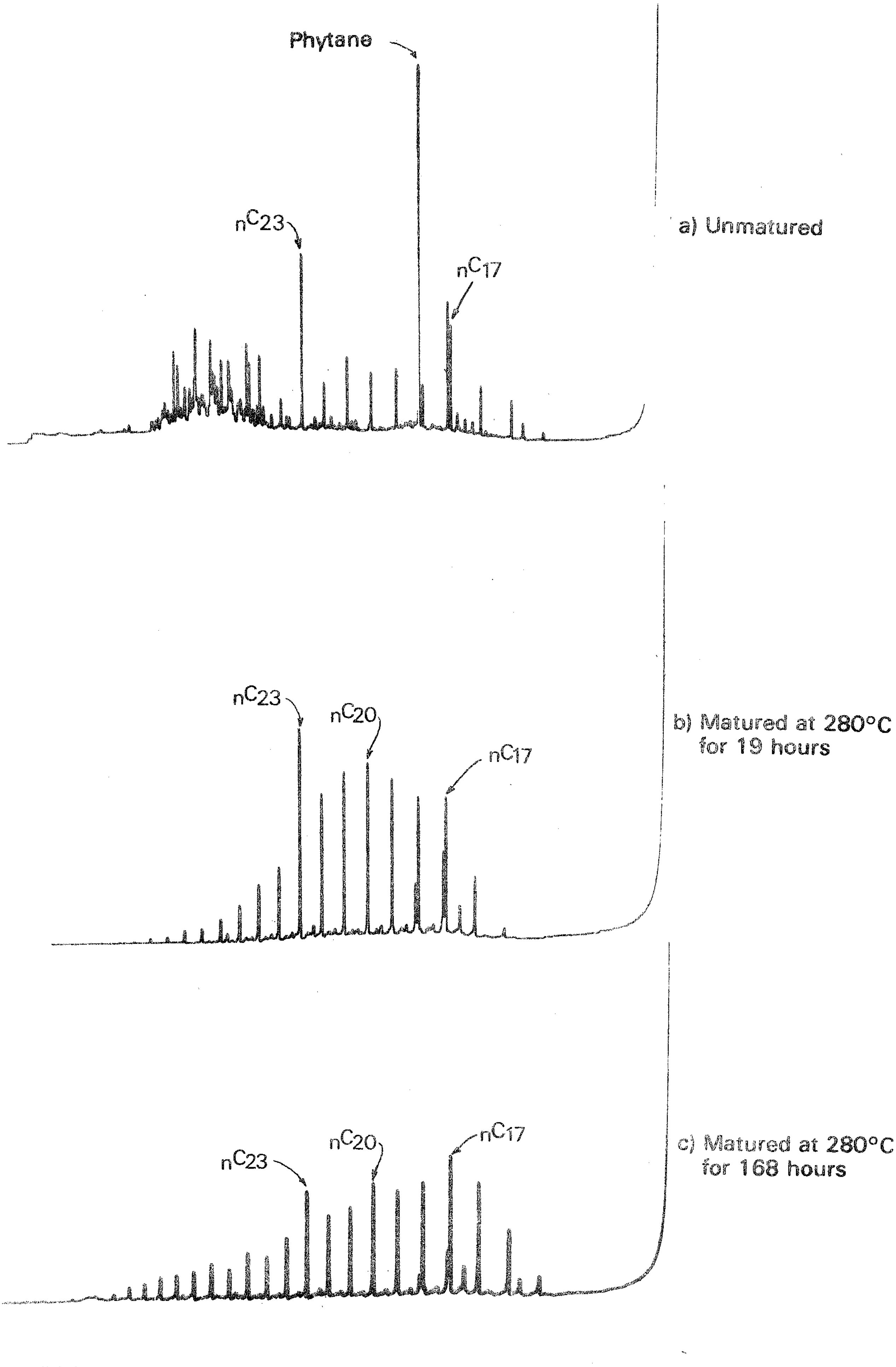


a) Unmatured

b) Matured at 280°C
for 19 hours

c) Matured at 280°C
for 168 hours

Maturation experiment: saturated hydrocarbon fractions derived from KOS 950

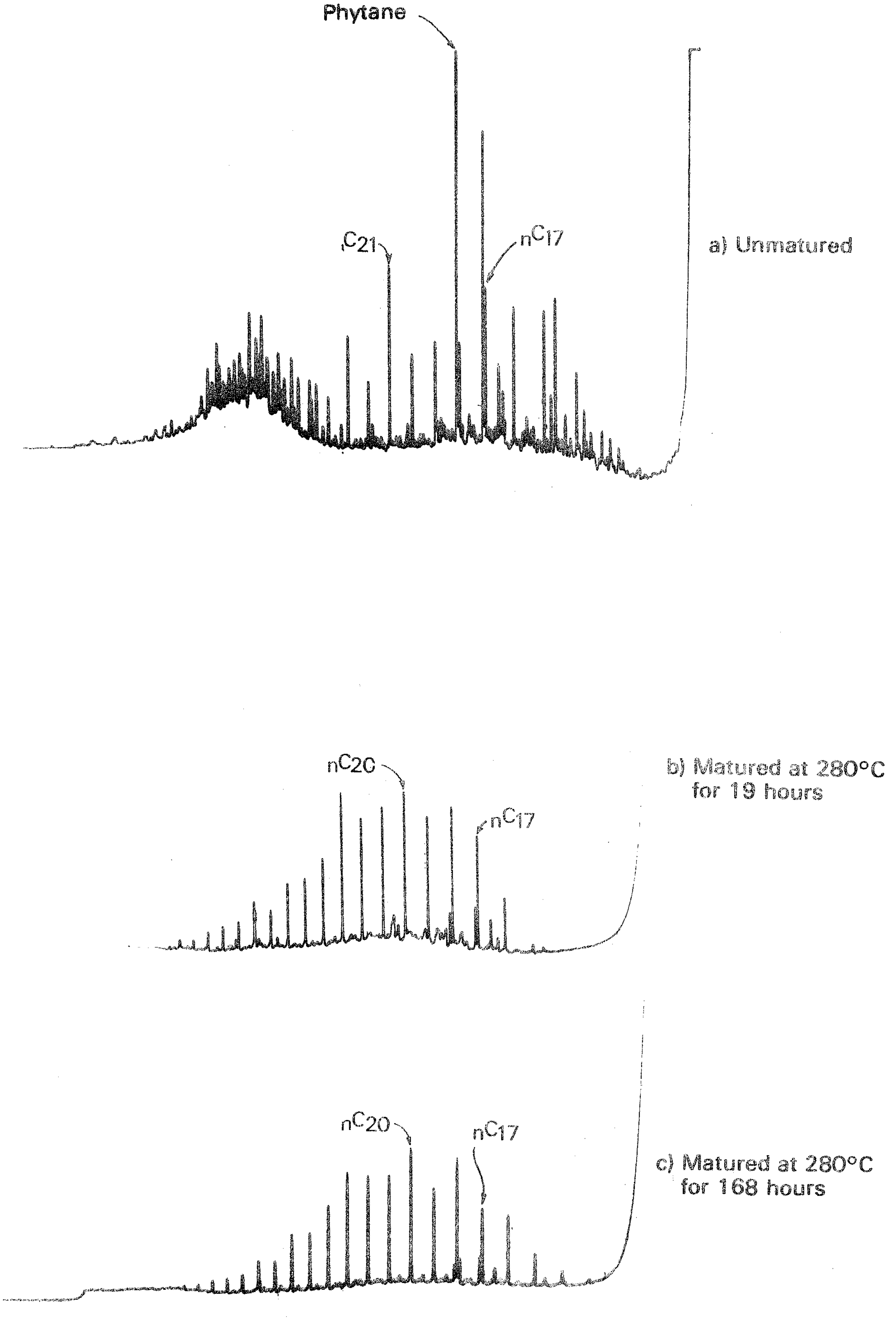


a) Unmatured

b) Matured at 280°C for 19 hours

c) Matured at 280°C for 168 hours

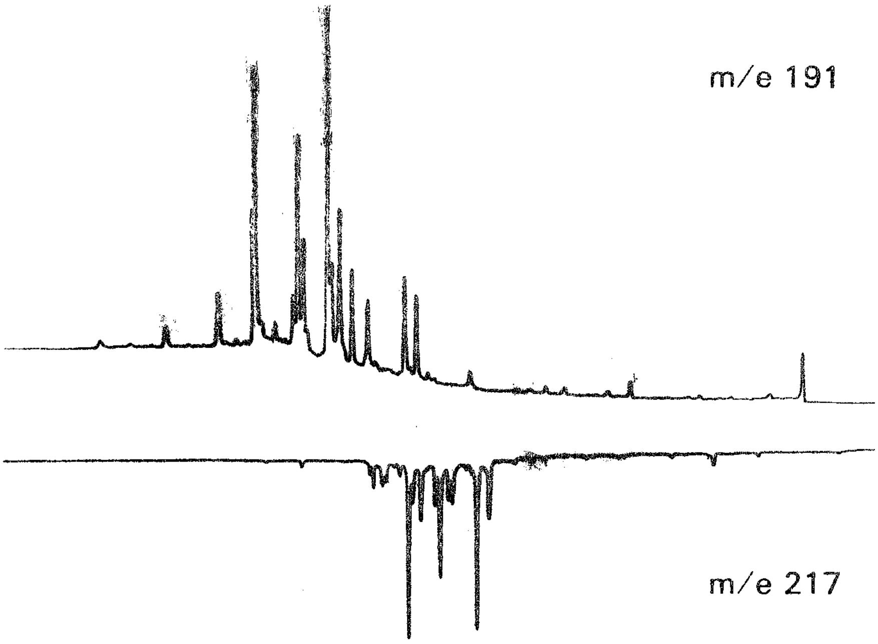
Maturation experiment: saturated hydrocarbon fractions derived from KOS 953



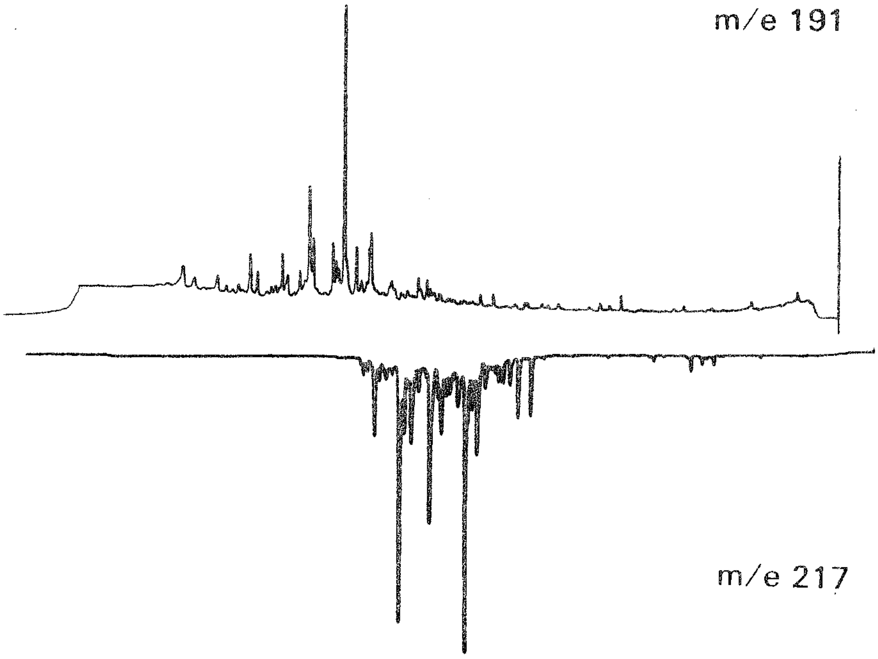
Maturation experiment: saturated hydrocarbon fractions derived from KOS 956

Bitumen
saturated hydrocarbons

KOS 950



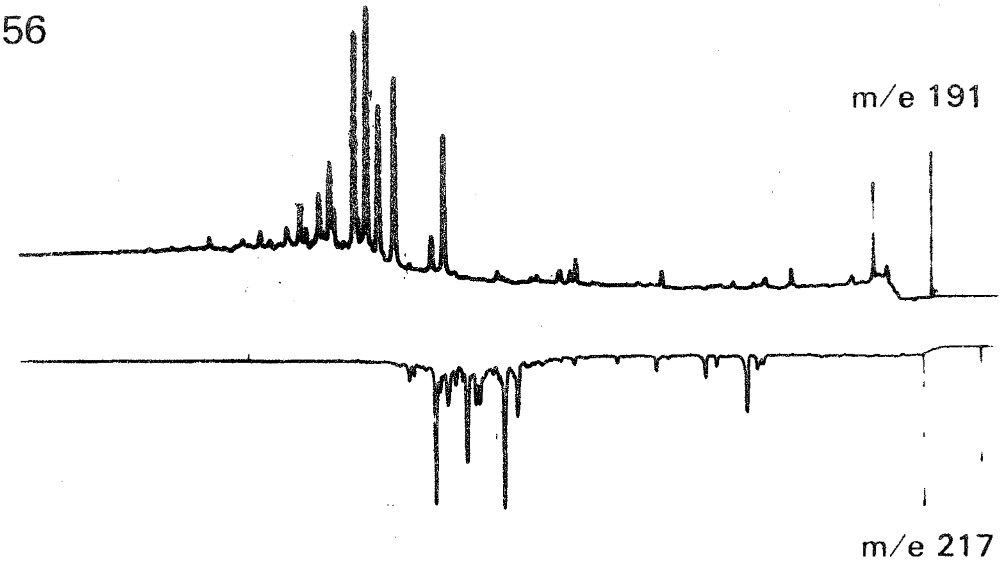
KOS 955



Multiple ion detection mass chromatograms

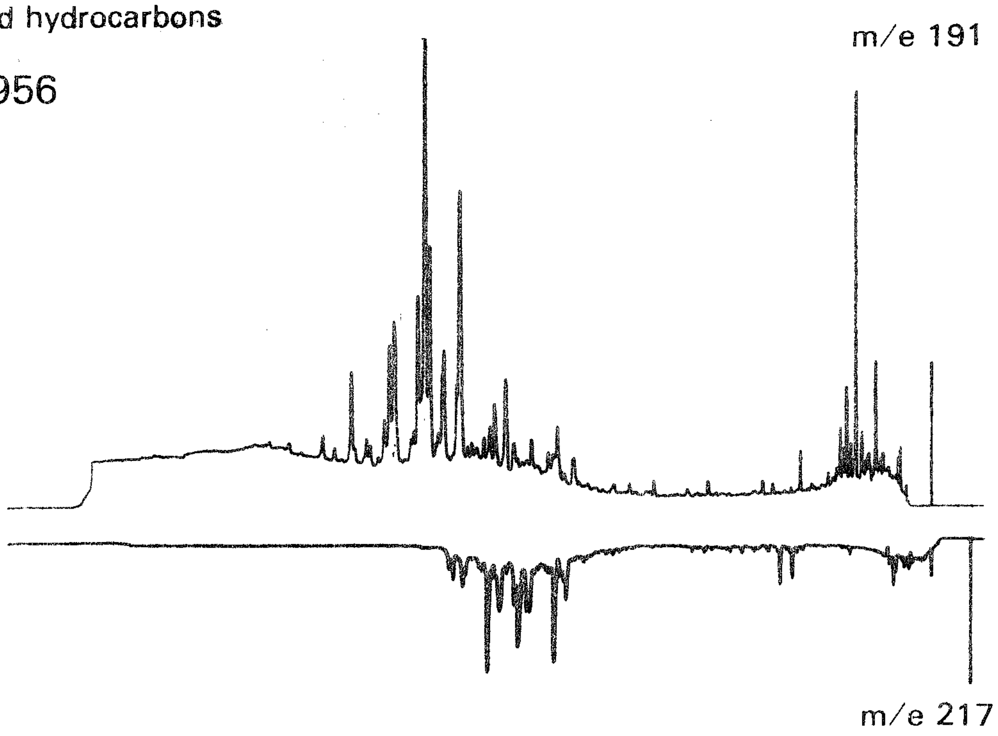
Shale oil
saturated hydrocarbons

KOS956



Bitumen
saturated hydrocarbons

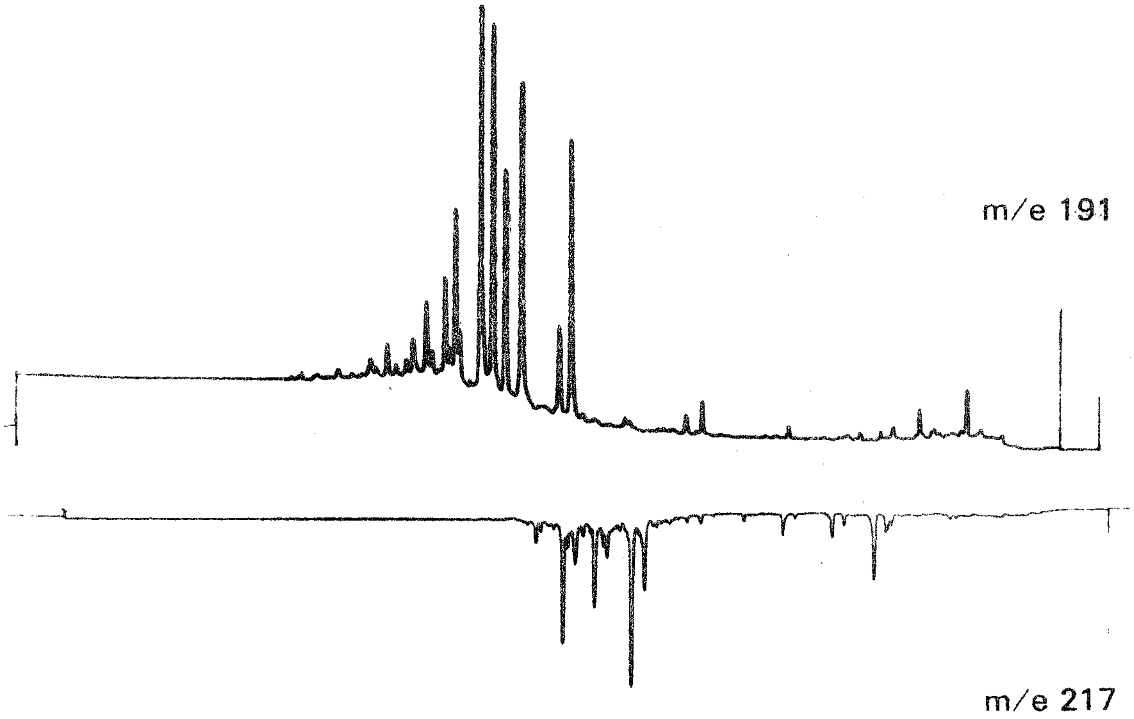
KOS956



Multiple ion detection mass chromatograms

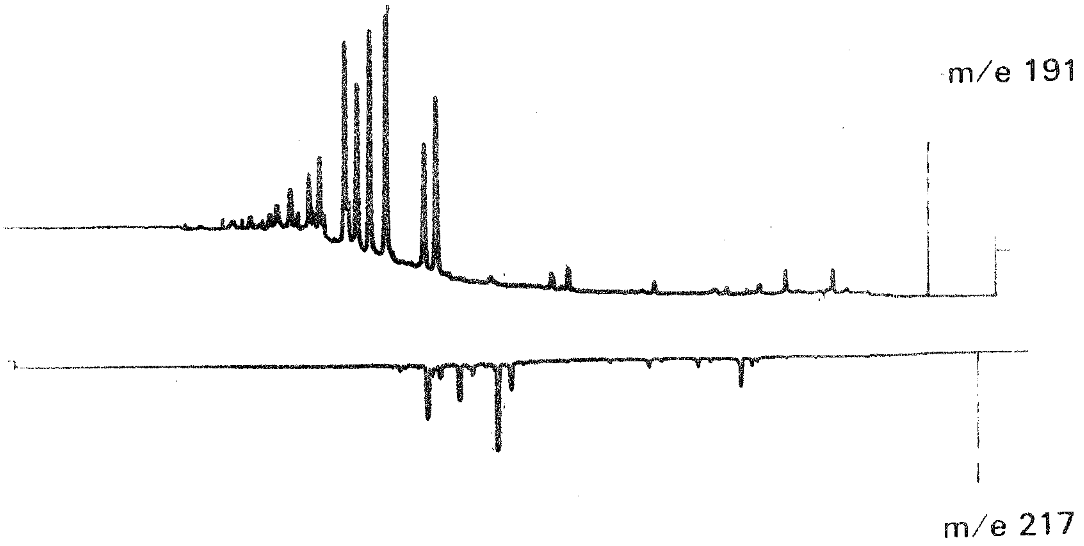
Shale oil
saturated hydrocarbons

KOS 963

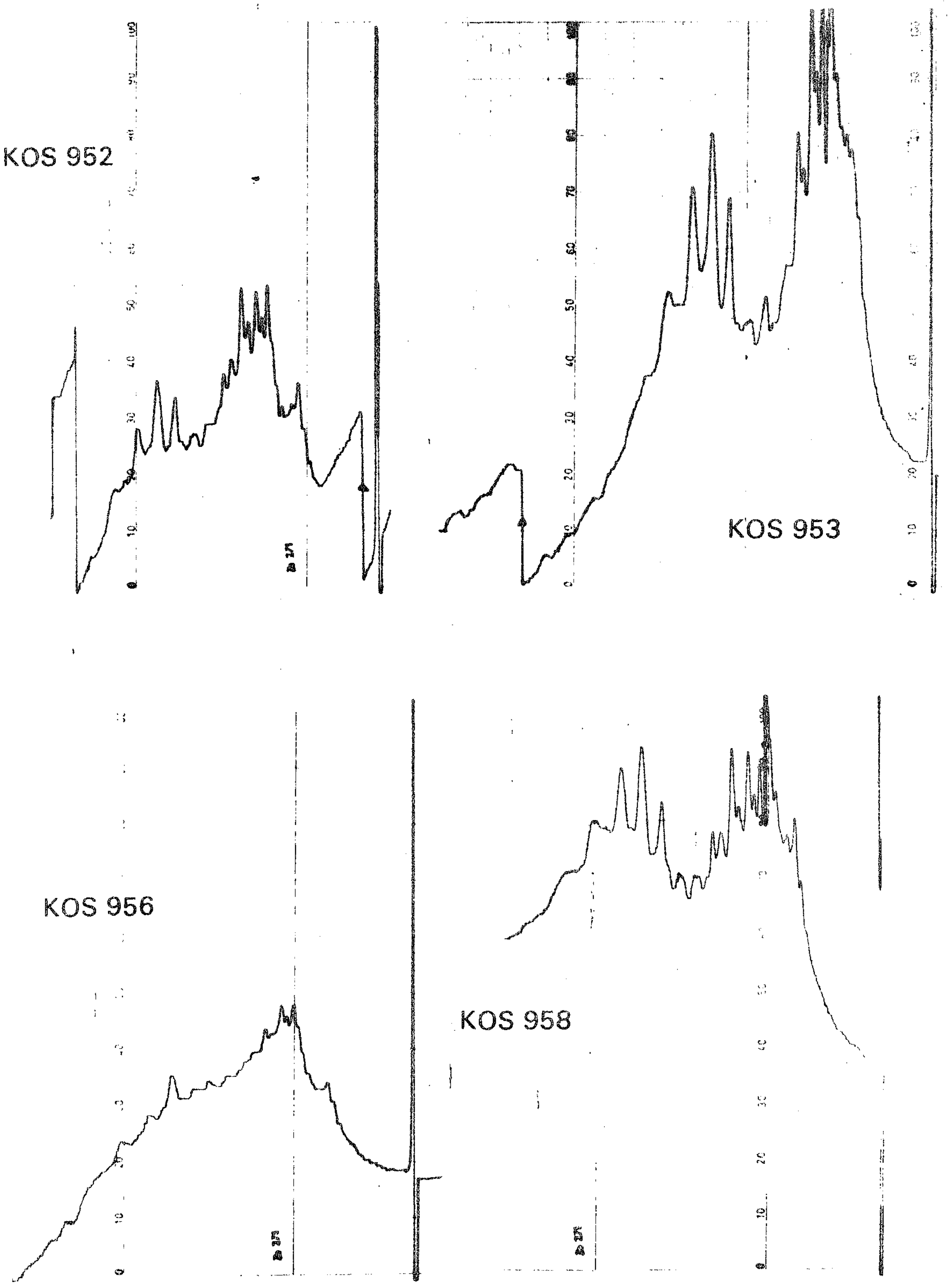


Shale oil
saturated hydrocarbons

KOS 968

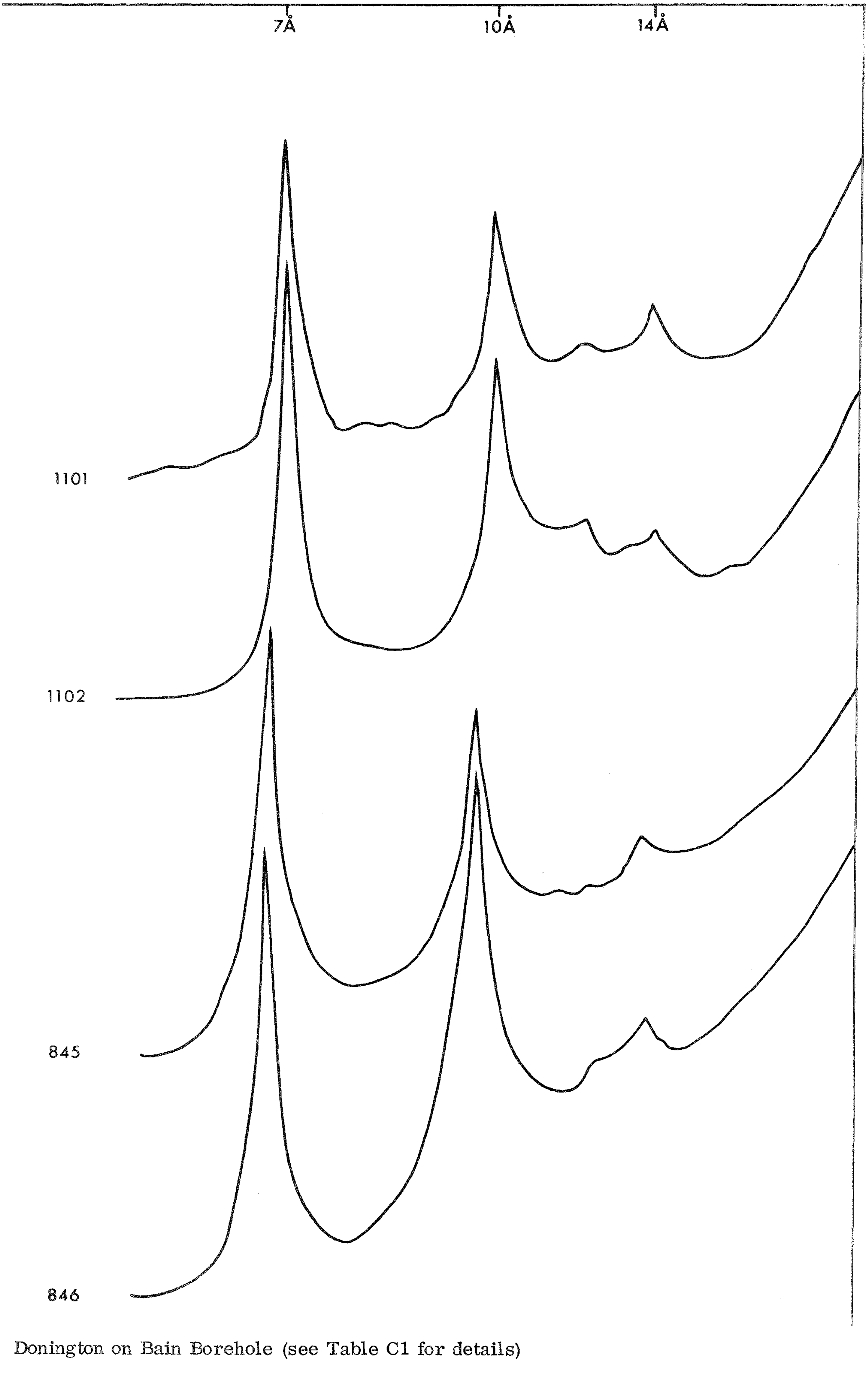


Multiple ion detection mass chromatograms

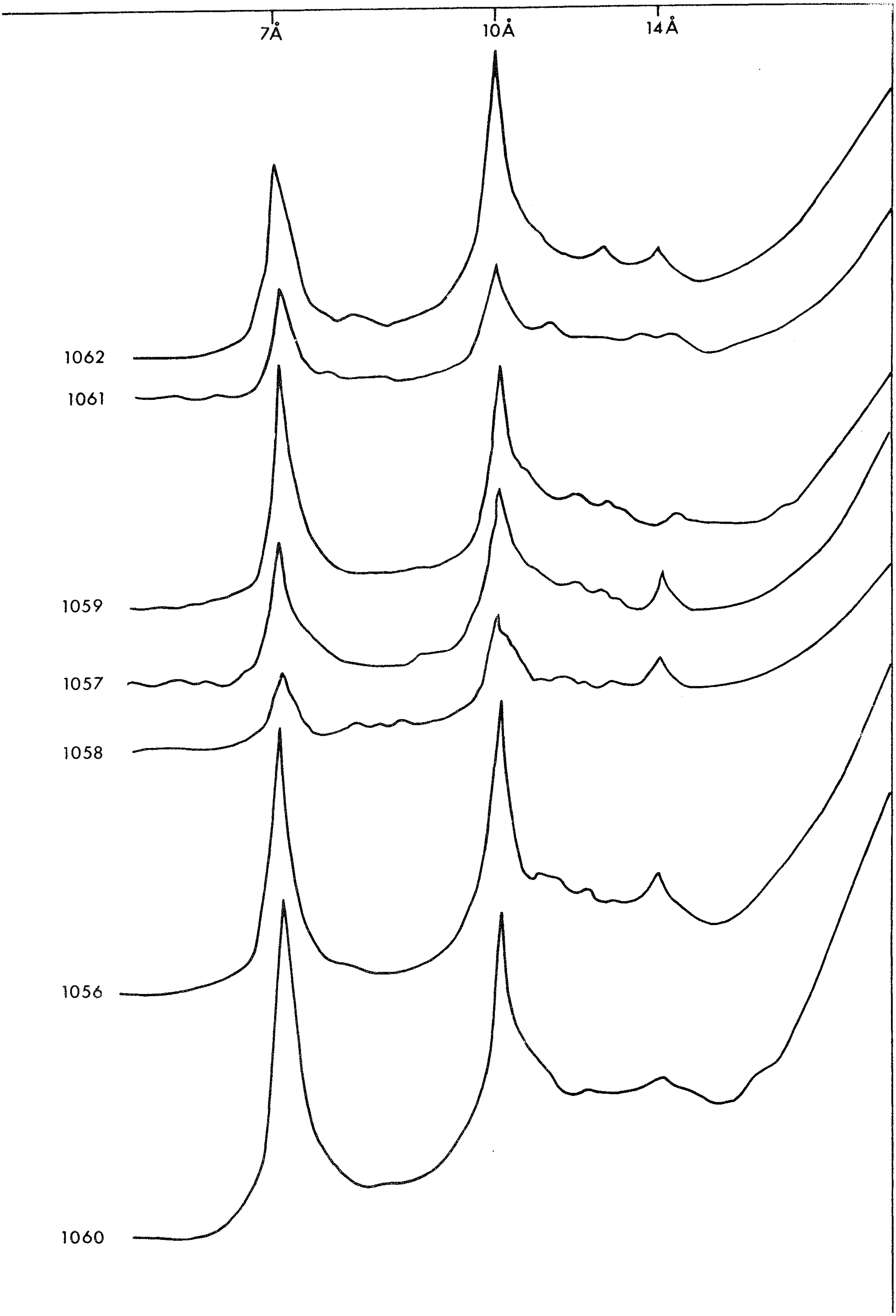


High pressure liquid chromatograms of shale oil aromatic hydrocarbons

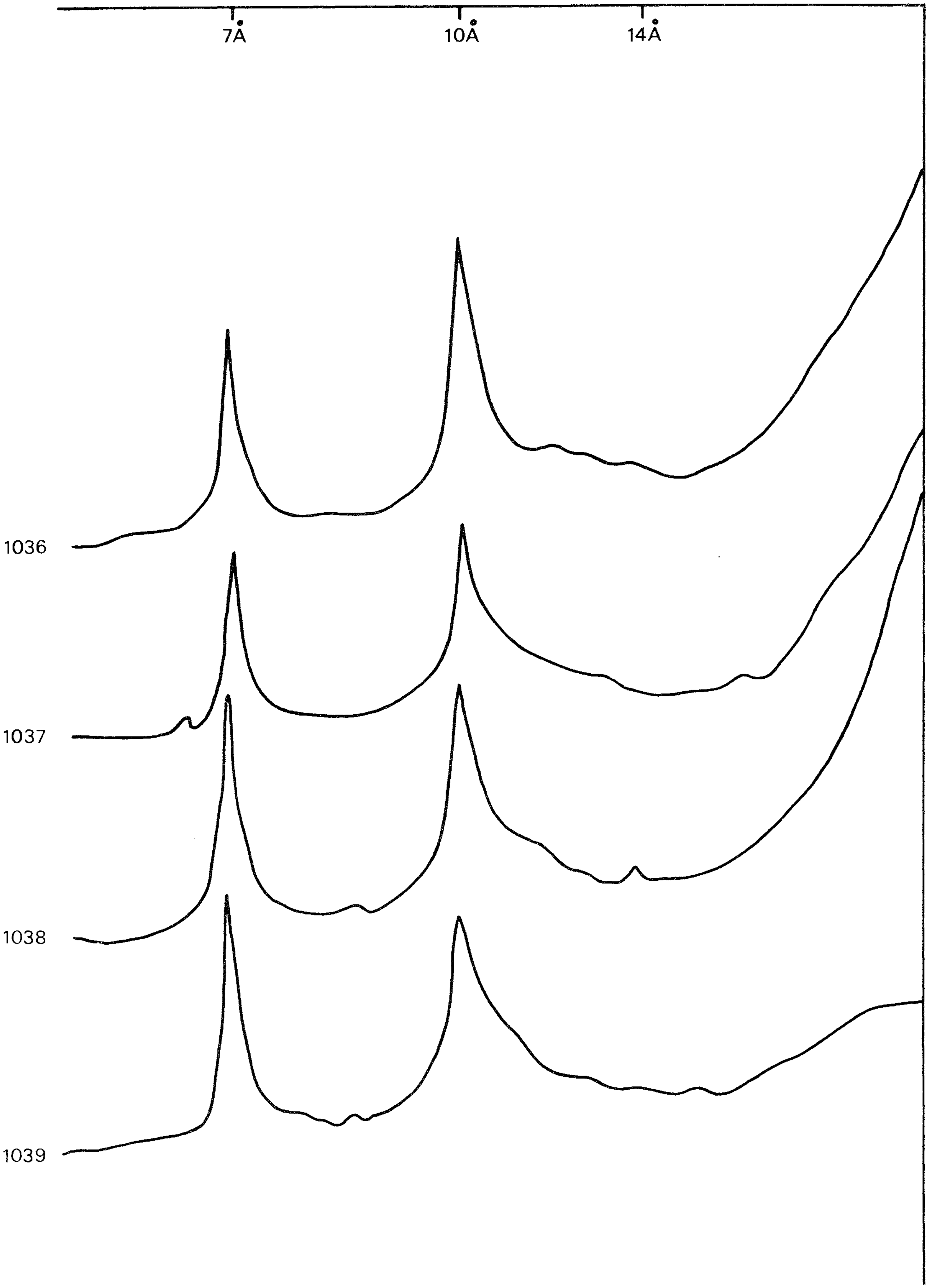
Appendix I:
X-ray diffractograms



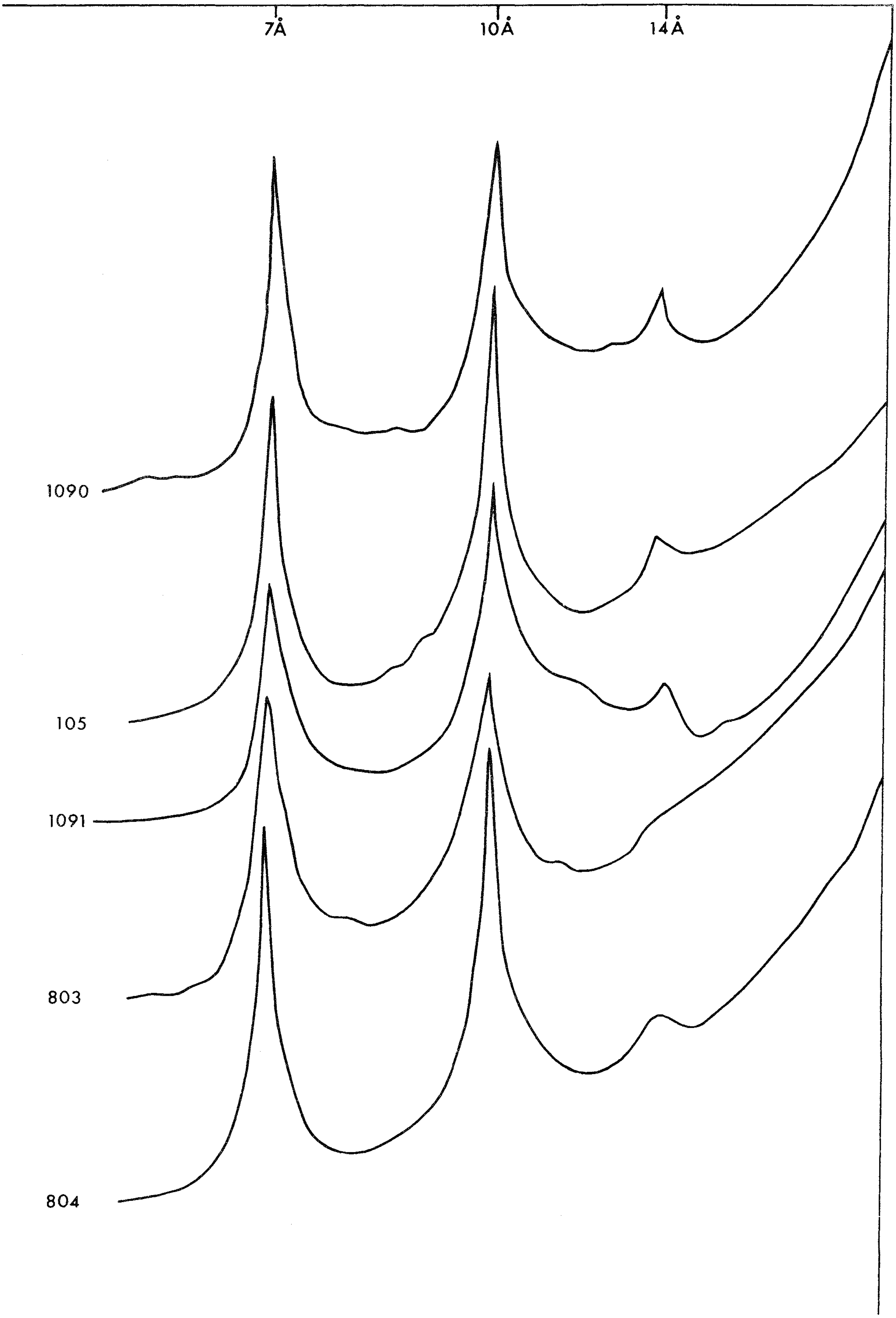
Donington on Bain Borehole (see Table C1 for details)



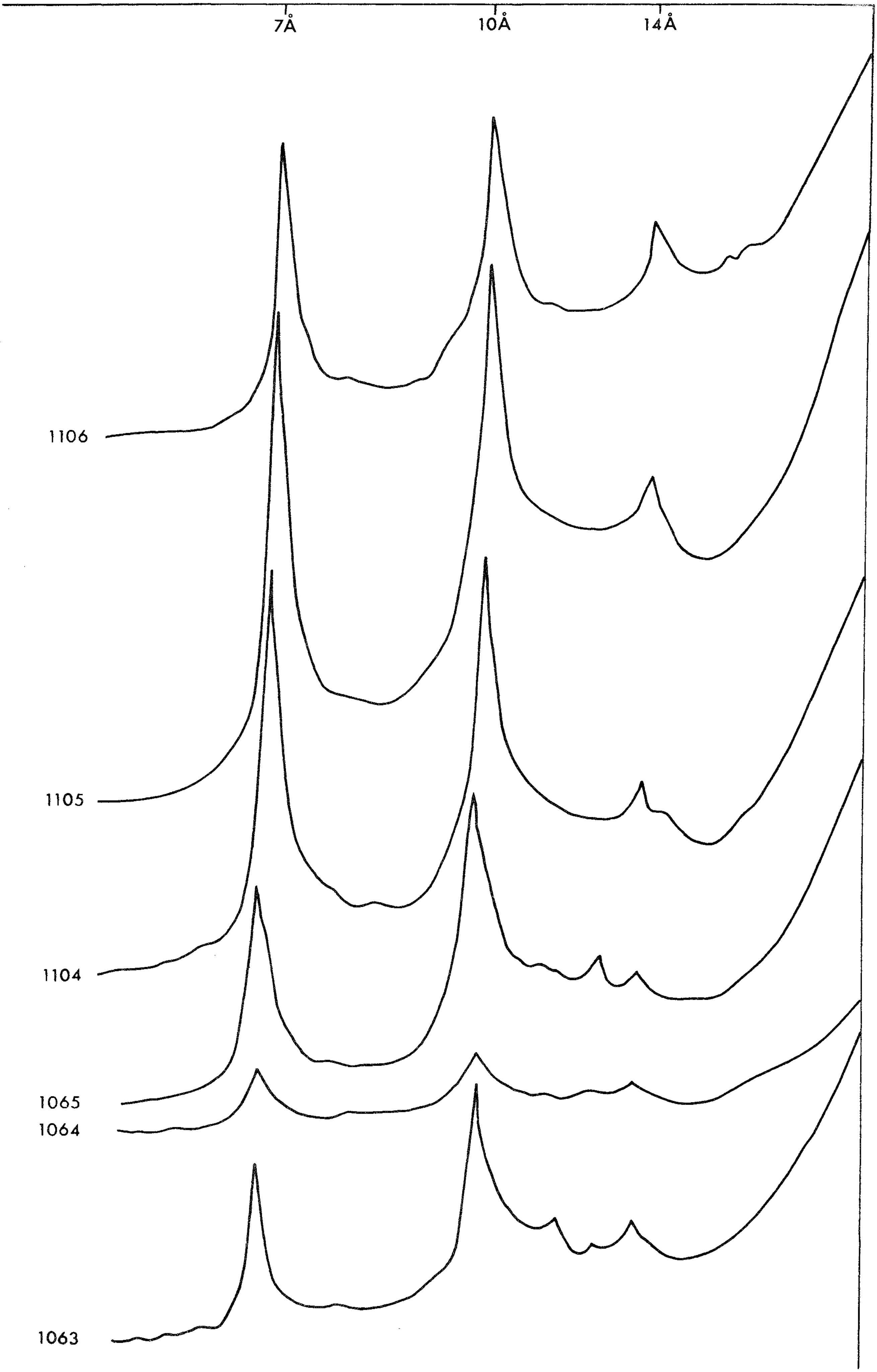
Foudry Bridge Borehole (see Table C1 for details)



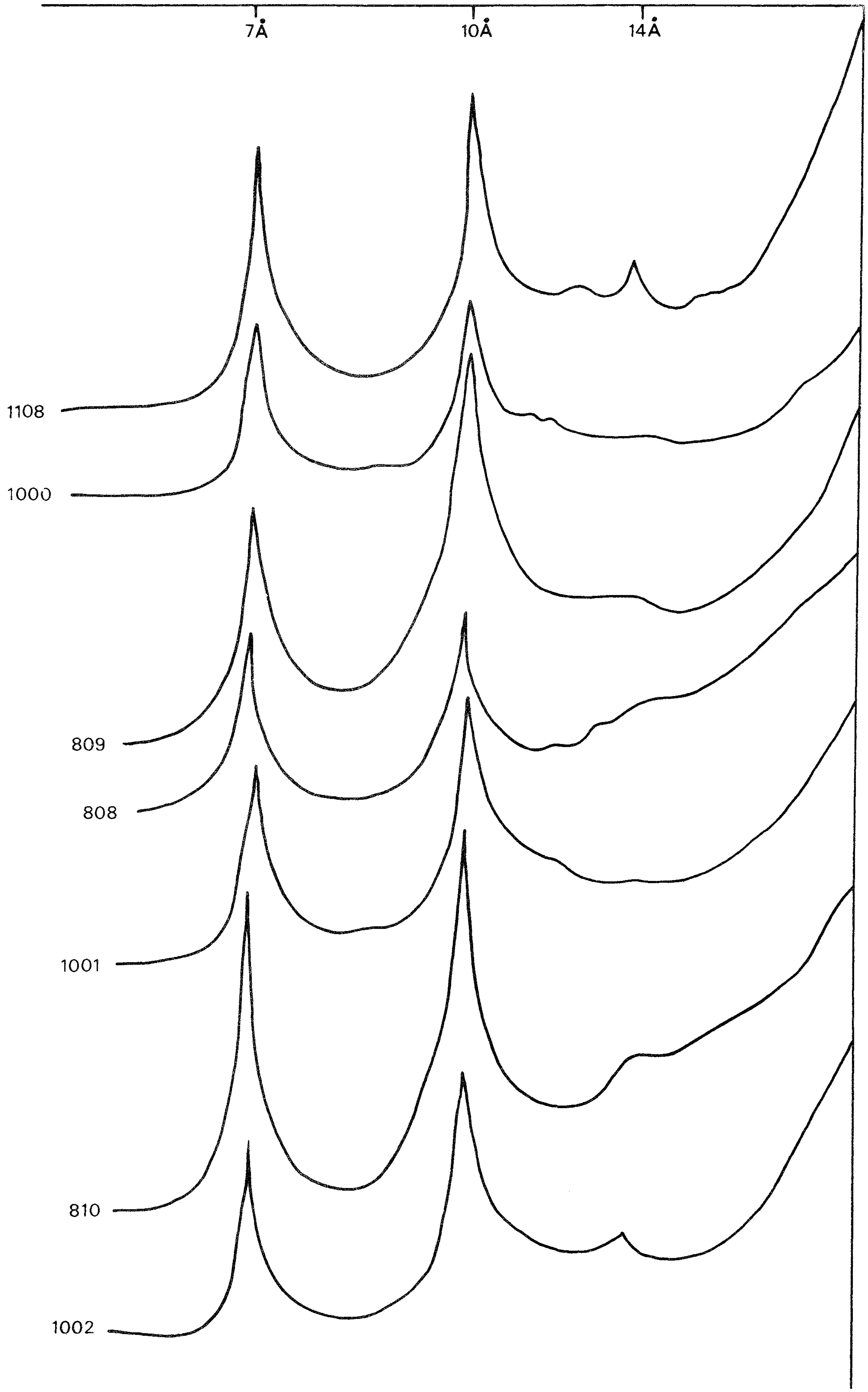
Encombe Borehole (see Table C1 for details)



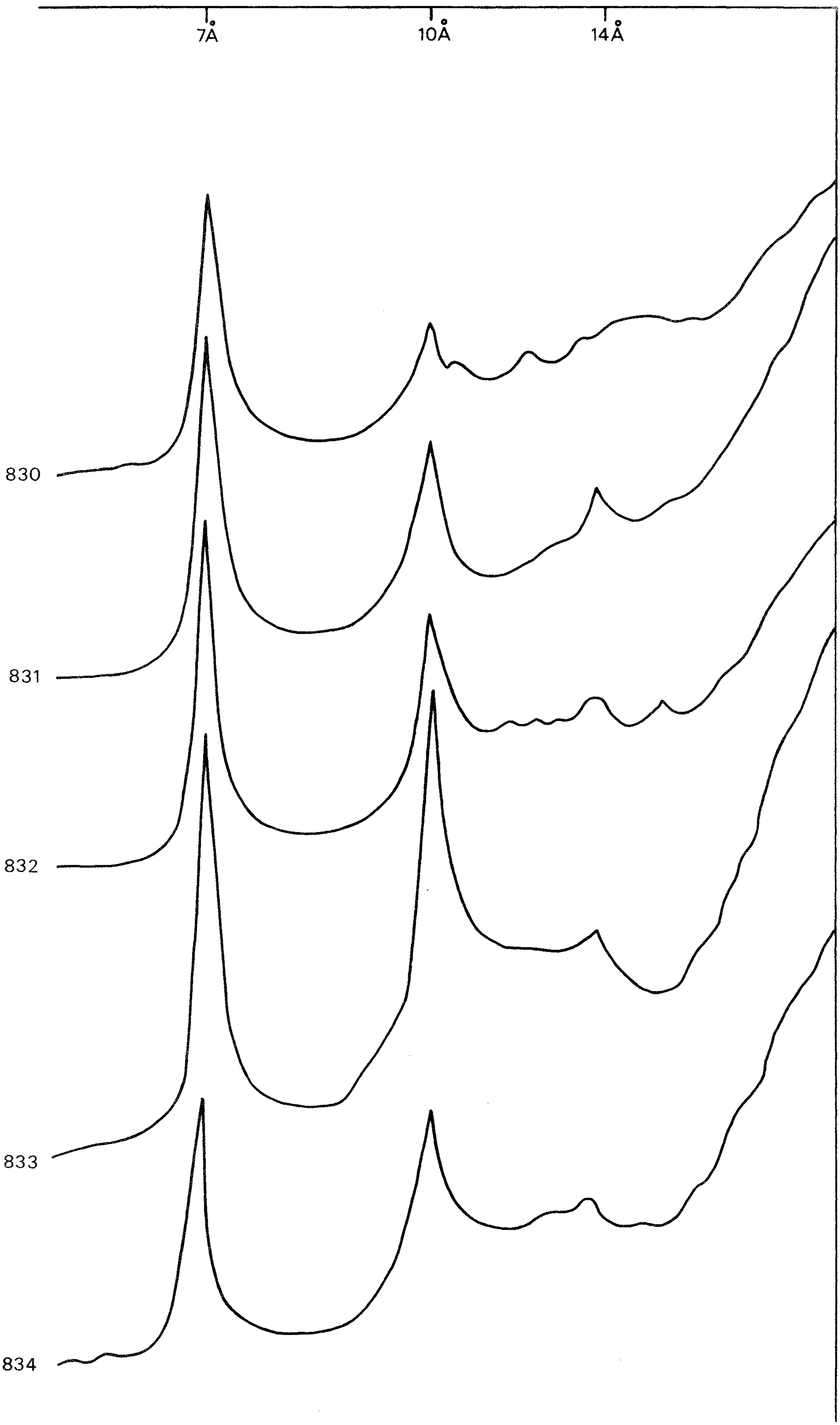
North Runcton Borehole (see Table C1 for details)



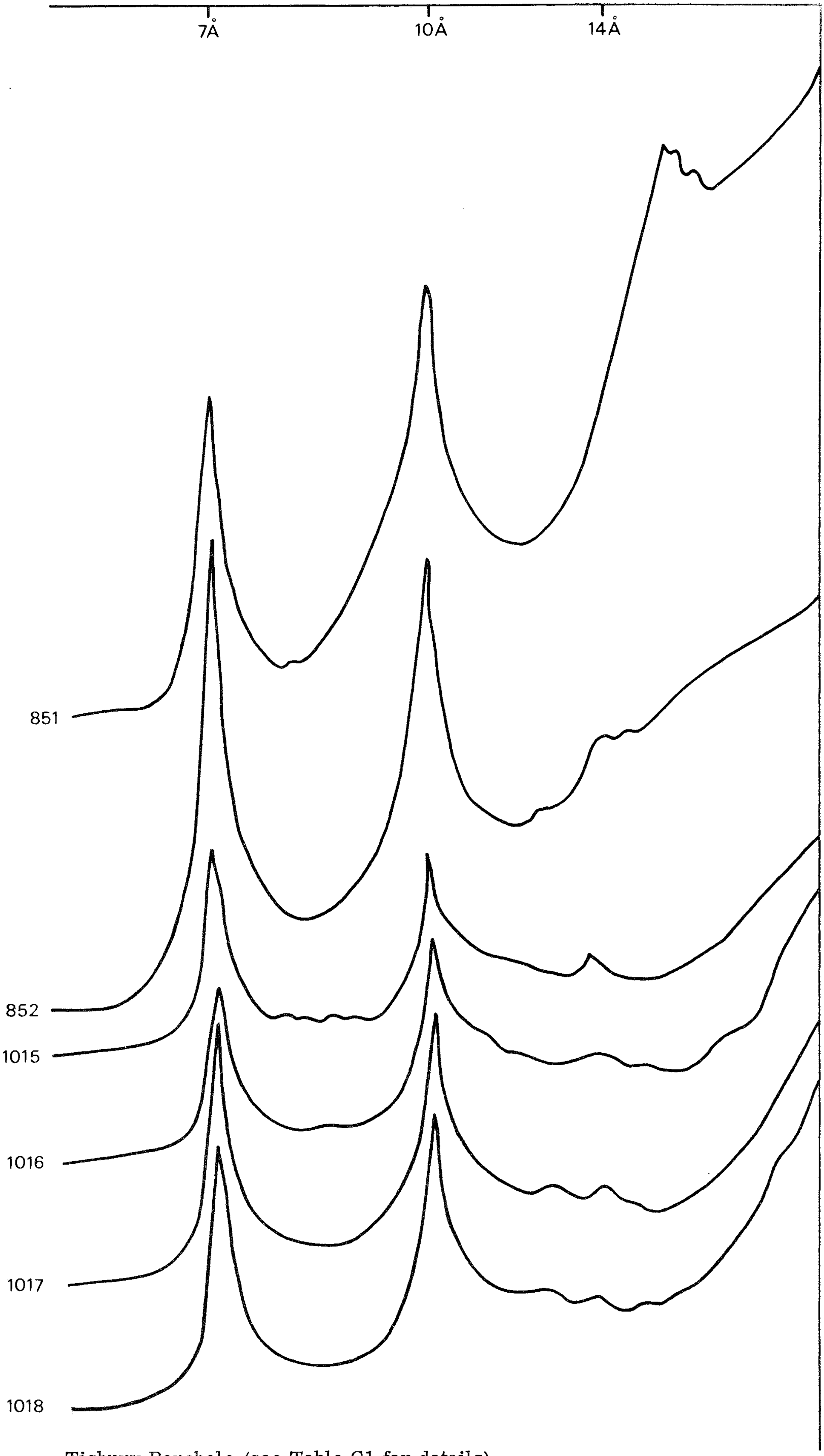
Foudry Bridge Borehole (see Table C1 for details)



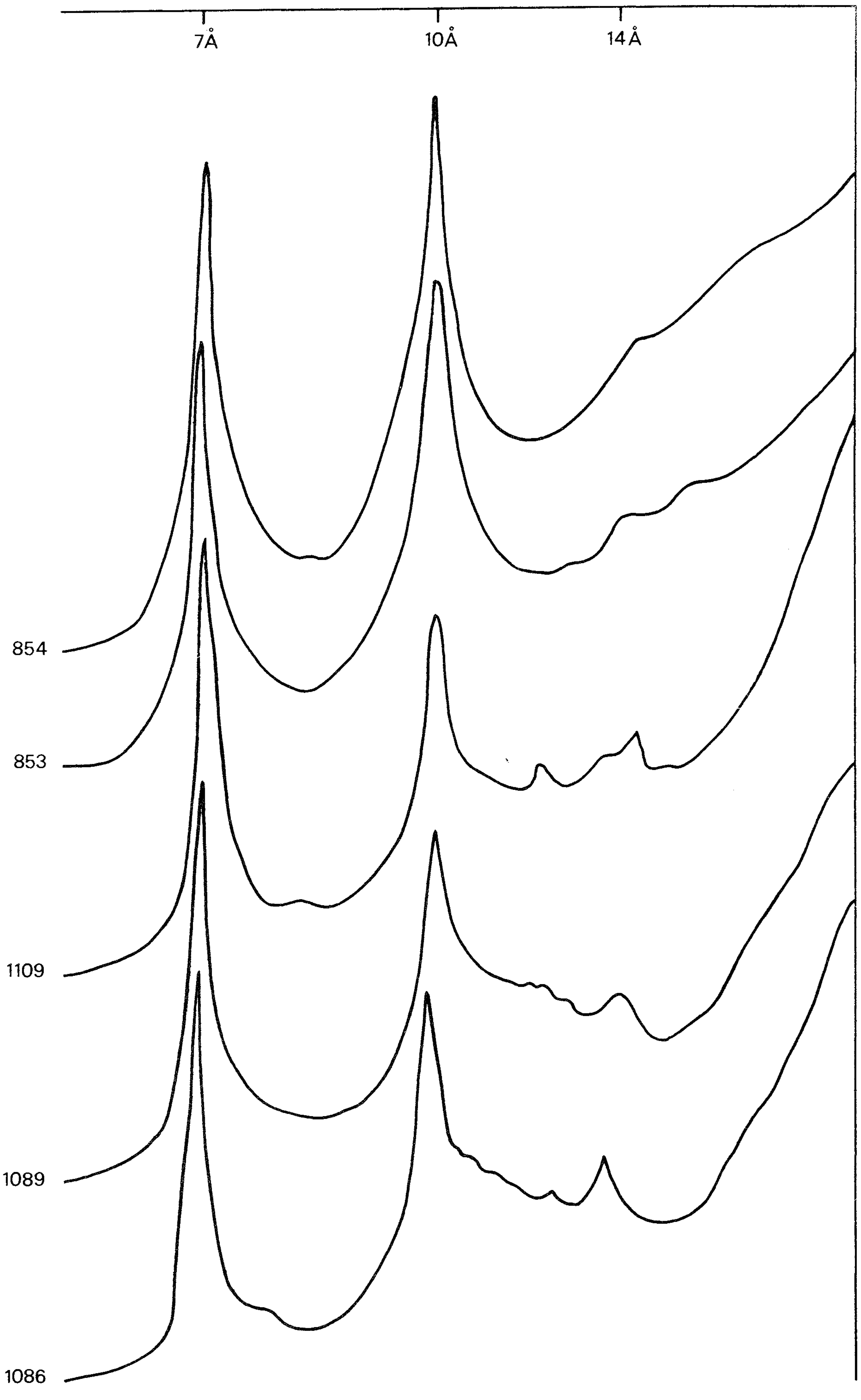
Portesham Borehole (see Table C1 for details)



Reighton Borehole (see Table C1 for details)

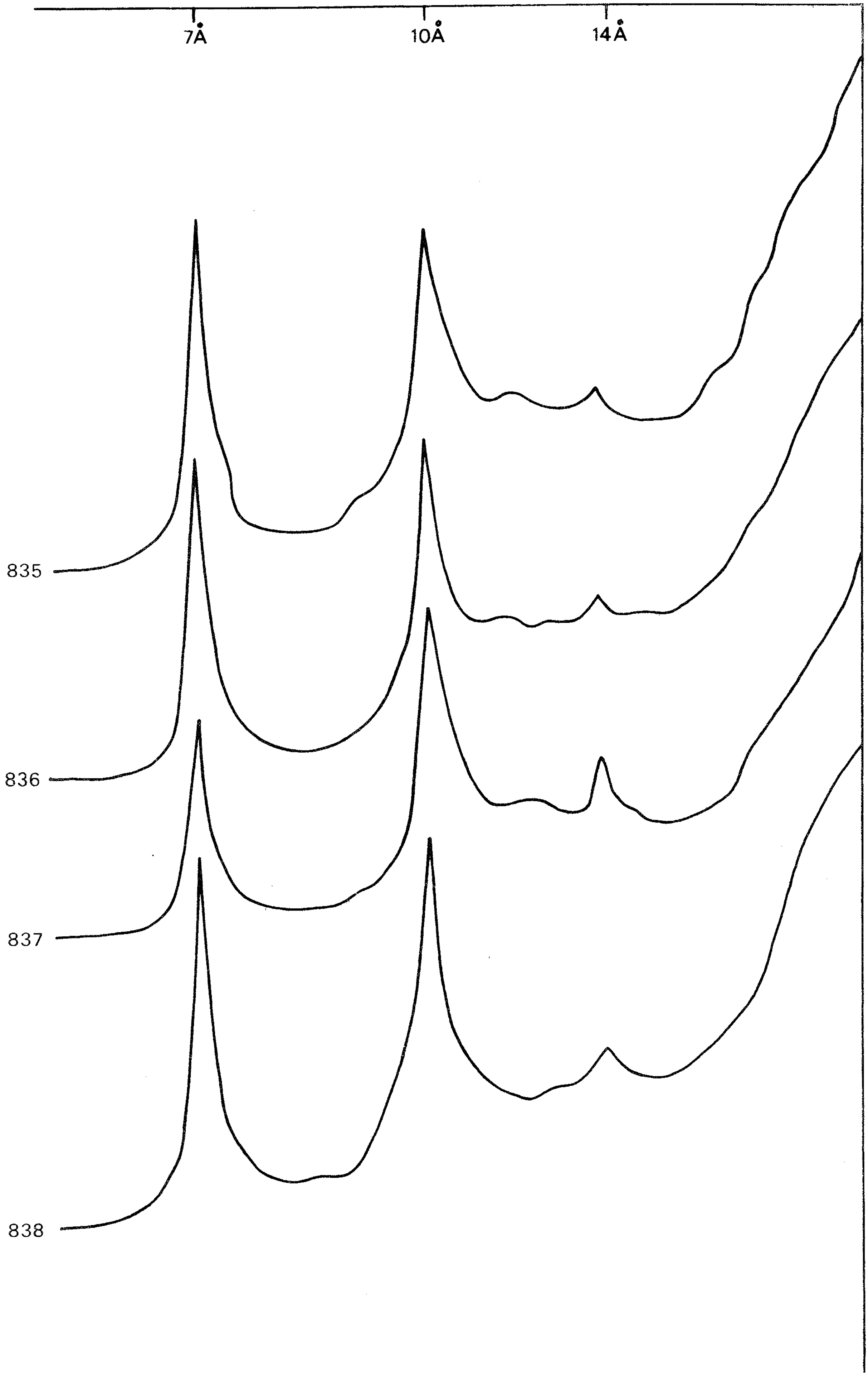


Tisbury Borehole (see Table C1 for details)

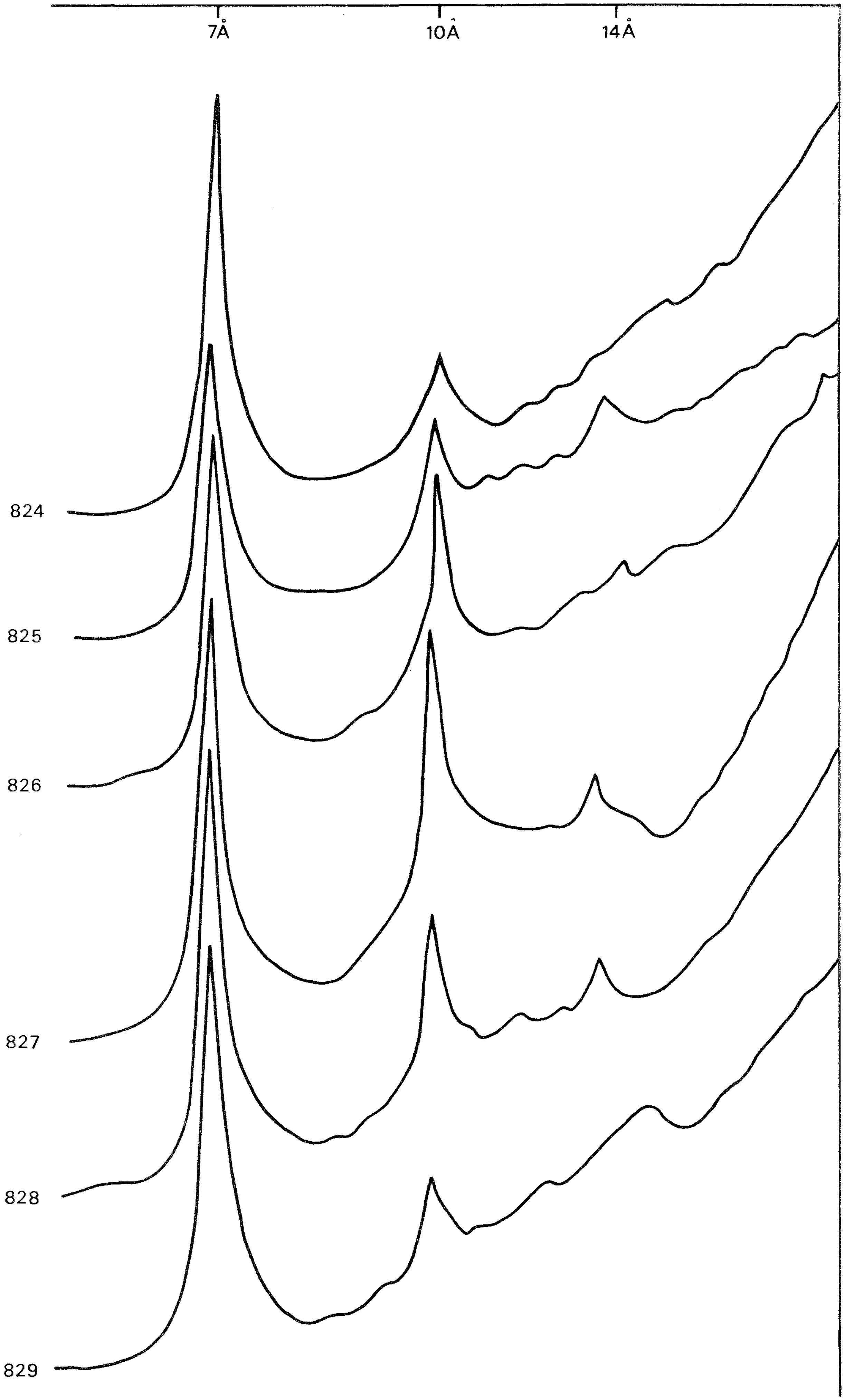


West Lavington Borehole (see Table C1 for details)

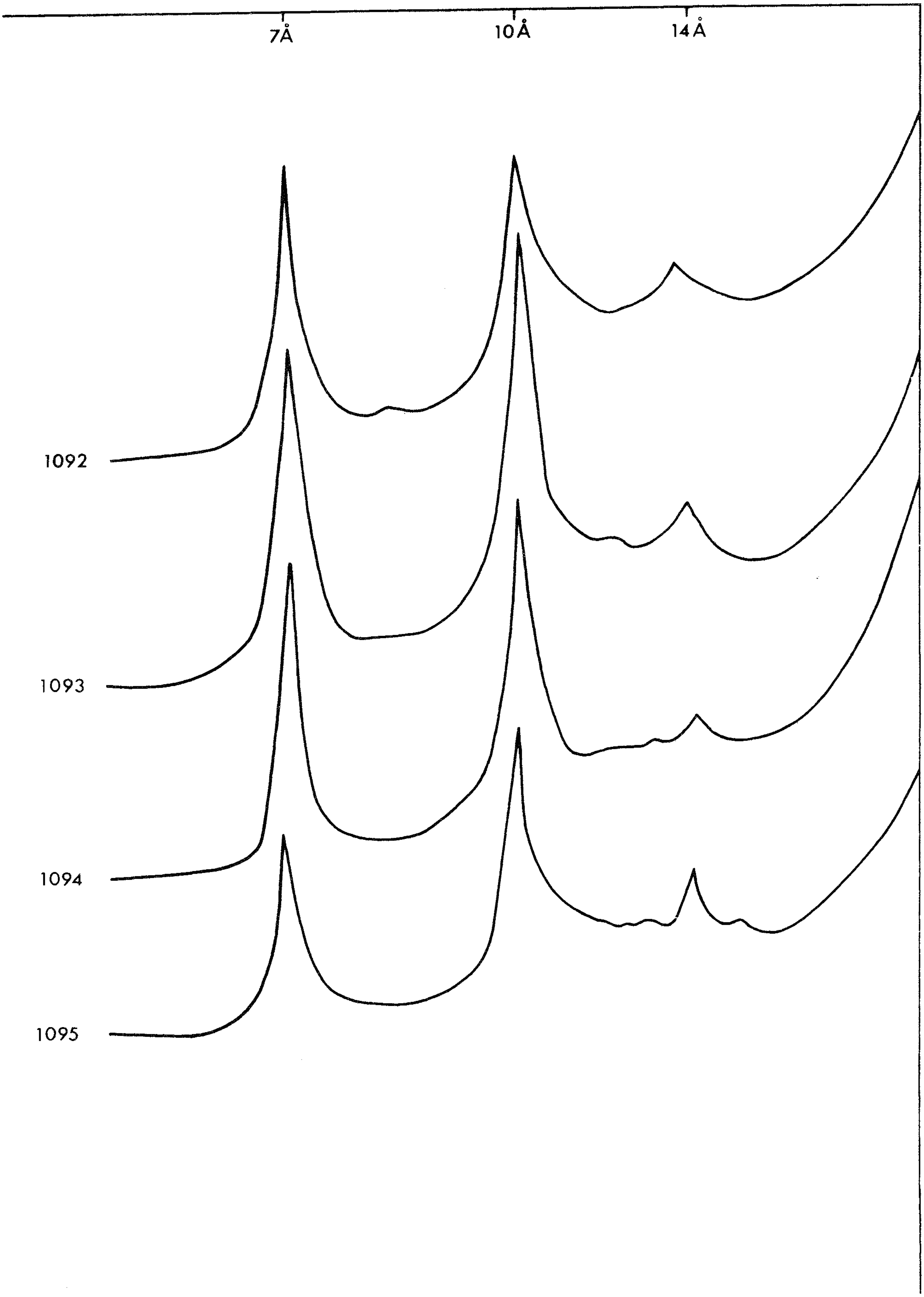
Donington on Bain Borehole (see Table C1 for details)



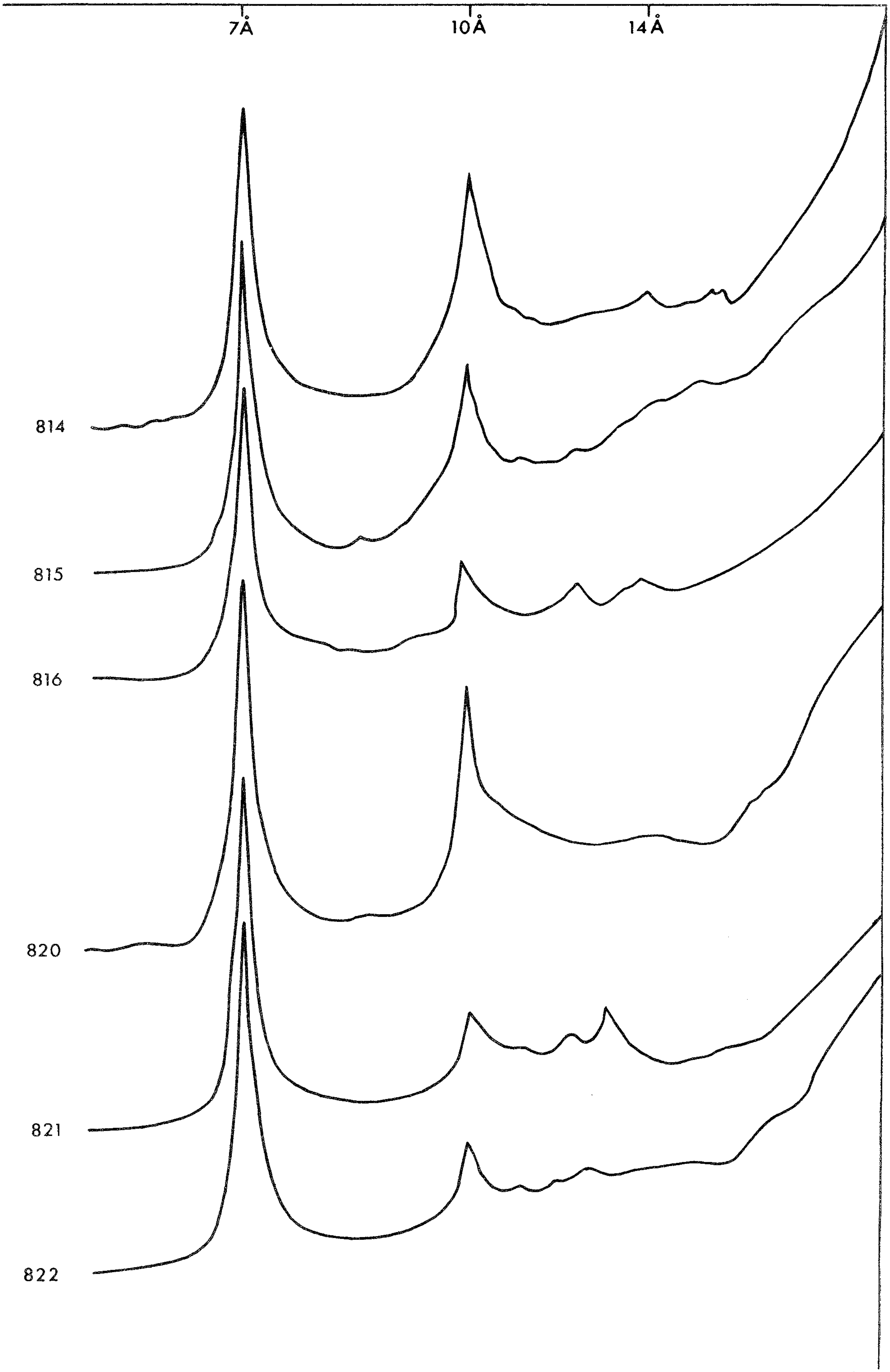
Reighton Borehole (see Table C1 for details)



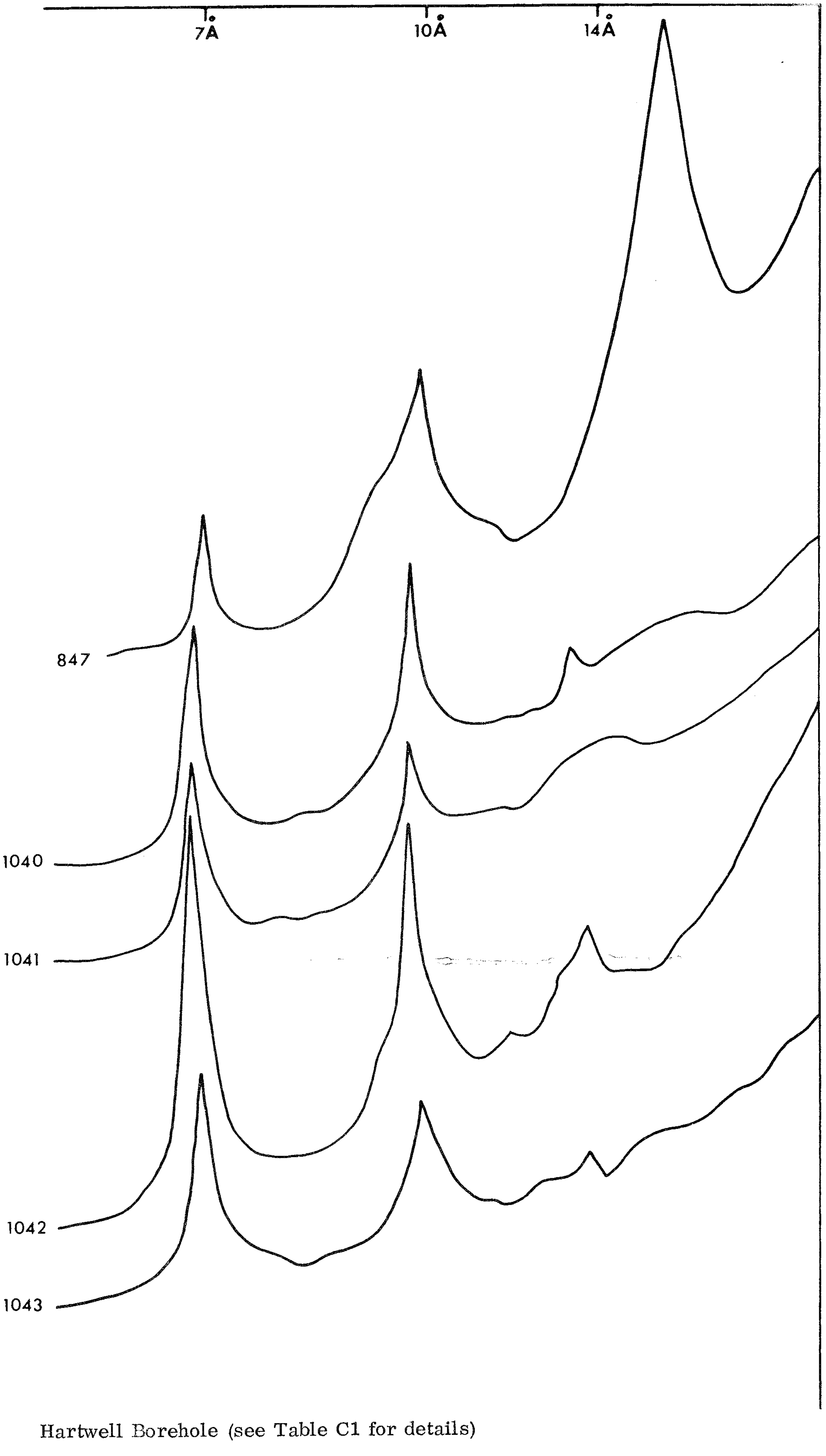
Reighton Borehole (see Table C1 for details)



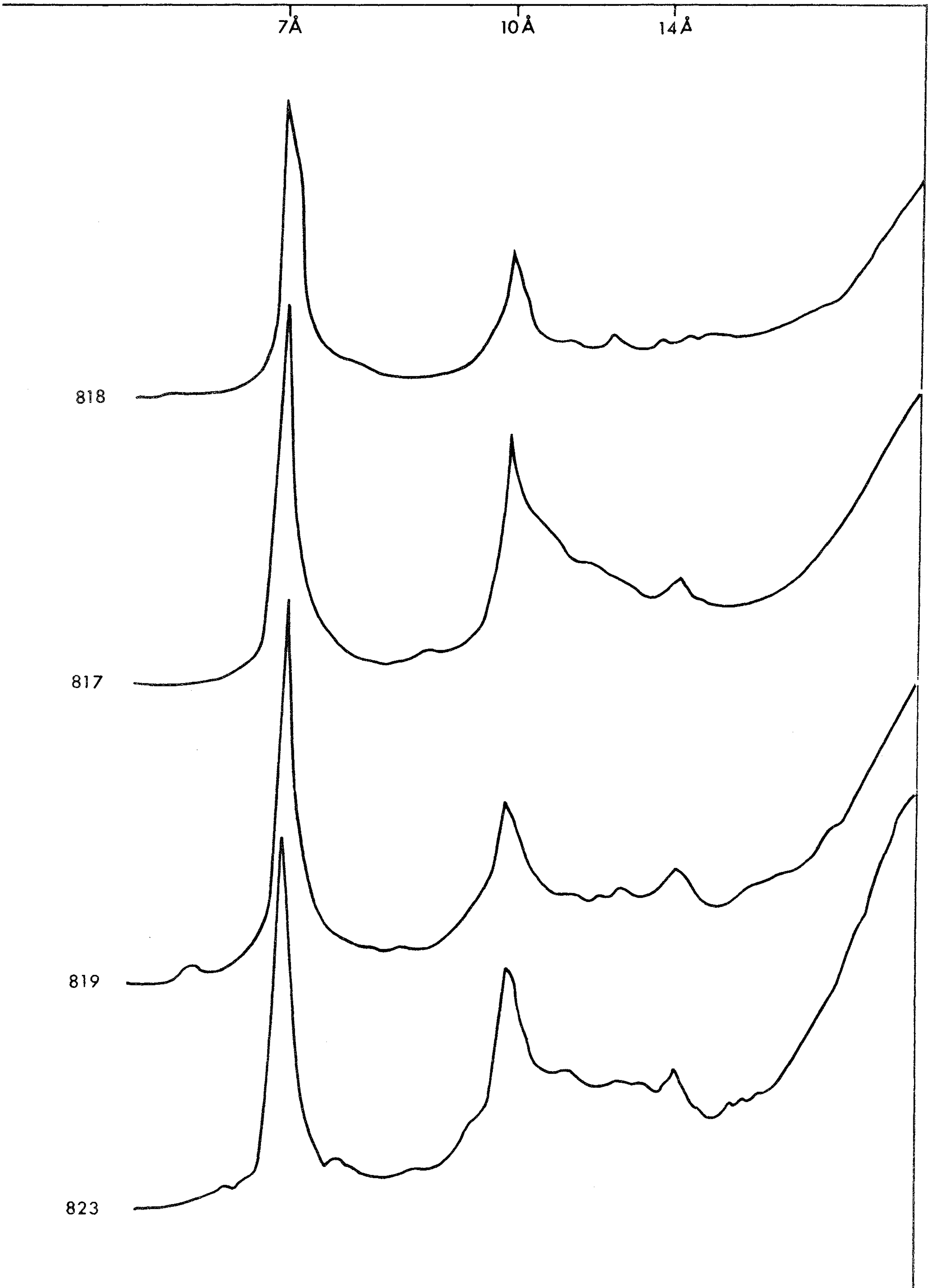
North Runcton Borehole (see Table C1 for details)



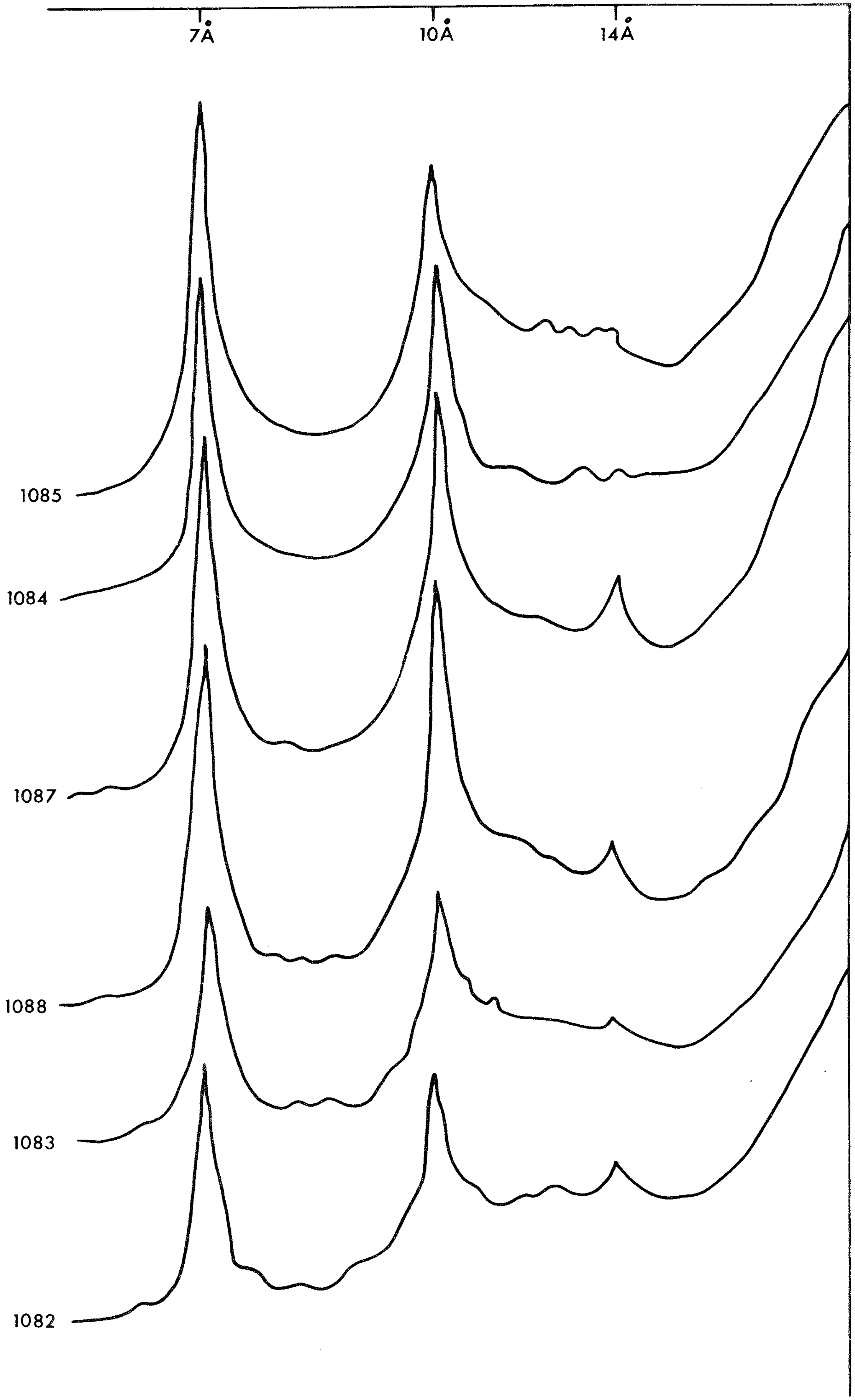
Marton Borehole (see Table C1 for details)



Hartwell Borehole (see Table C1 for details)



Marton Borehole (see Table C1 for details)



West Lavington Borehole (see Table C1 for details)