

## ABSTRACT

According to maceral composition and organic facies, hydrogen and oxygen indices (from Rock-Eval pyrolysis) and analysis of various maturation parameters ( $R_o$ , TAI and  $T_{max}$ ) of one hundred thirty five samples, multiple source rocks of Kerogen Types IIA (one), IIA-IIB (seven), IIB (twenty-seven), IIB-III (sixteen), III (eighty) are identified in various stratigraphic levels; four samples are considered as nonsource for any minor oil/condensate/gas. Accordingly, 59.3% of the source rocks can generate only gaseous hydrocarbons, 11.9% can generate mainly gas with minor condensate, 20.0% will generate mainly condensate with minor gas, 5.2% of the source rocks can generate equal amounts of condensate and crude oil with minor gas and 0.7% of the source rocks can mainly generate crude oil with minor condensate and gas. The organic facies and maturation data also indicate the possible presence of deep condensate and gas reservoired in currently unexplored regions of the Scotian Shelf.

Multiple linear regression and cluster analysis of aromatic GC-MS parameters reveals a closely related family of oils including oils from the wells Chebucto K-90, N. Triumph B-52, Olympia A-12, S. Venture O-59 (two samples), Glenelg J-48, Bluenose 2G-47, Arcadia J-16, Venture H-22 and Thebaud C-74. Three rock extracts, from the wells Venture B-52 (5121m), Thebaud C-74 (3911m) and S. Desbarres O-76 (3861m), match those light oil/condensates mentioned above, according to the cluster analysis. Those rocks should be evaluated as potential source for the liquid hydrocarbons. The extracts of those source rocks also show close similarity in n-alkane distribution pattern and isotope data.

A second oil family, whose members are less closely related than the first (according to the multiple regression and cluster analysis of aromatic GC-MS parameters), includes light oil from Cohasset D-42 and A-52, Panuke B-90 and Sable Island 3H-52. None of the analyzed source rocks (from 135 samples) match with those oils for oil-source correlation. Isotope data of saturate and aromatic fraction of the extracts do not reveal any clear groupings of these two oil families.

The great majority of light oil/condensates and rock extracts in this study are at advanced levels of thermal maturity (middle to late oil window), as indicated by values of the Methylphenanthrene, Dimethylphenanthrene, Chrysene,  $C_3$ -Alkyl-naphthalene and  $C_4$ -Alkyl-naphthalene Indices. These data corroborate the data of the other maturity parameters like  $R_o$ , TAI and  $T_{max}$  for the source rock extracts.

The source rock extracts from wells Alma F-67 (2 samples), S. Venture O-59, W. Chebucto K-20 and Whycocomagh N-90 correlate with each other, according to the cluster analysis of aromatic hydrocarbons, but do not match any of the petroleum. These rock extracts and the rock extract samples from N. Triumph G-43 (2 samples) and Penobscot L-30 wells contain higher thiophenic sulfur suggesting input of more marine organic matter. These data corroborate quite well with the data from organic petrography and gas chromatography (saturate fraction).

## TABLE OF CONTENTS

Introduction	1-3
Administrative Aspect	1
Scientific Aspect	1-3
Samples	3
Analytical Methods	3-5
Source Rock Characterization	5-9
Total Organic Carbon	5-6
Organic Facies and Kerogen Type etc.	6-7
Rock-Eval Pyrolysis	7-8
Maturation by Vitrinite Reflectance, TAI, T <sub>max</sub>	8-9
Source Rock Potential	9
Genesis of Liquid Hydrocarbons and Oil-Source Correlation	9-19
Liquid and Gas Chromatography etc.	9-11
Stable Carbon Isotope	11-12
Biological Markers:Aromatic Hydrocarbons	12-20
Data Handling	12-15
Maturity Determination	15-17
Oil-Oil and Oil-Source Correlation	17-20
Summary and Conclusions	20-21
Source Rock Characterization	20
Genesis of Petroleum & Oil-Source Correlation	20-21
Acknowledgments	21-22
References	22-27
List of Tables	28
List of Figures	28-29

## **INTRODUCTION**

### ***Administrative Aspect***

This research proposal was requested by Supply and Services Canada (SSC), Dartmouth, Nova Scotia on April 12, 1991 according to the initiation of the Basin Analysis Subdivision of the Atlantic Geoscience Centre, Geological Survey of Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Accordingly, Global Geoenergy Research Ltd. of Halifax, Nova Scotia, submitted a financial and work schedule of the research proposal on April 16, 1991. The proposal was accepted on April 20, 1991. The Canada Nova Scotia Offshore Petroleum Board (CNSOPB), Halifax, Nova Scotia, on our request, permitted us to collect 135 unwashed cuttings and core samples from 21 selected Scotian Shelf wells from the CNSOPB-COGLA Repository at Dartmouth, Nova Scotia. According to the contract, the ISPG (Geological Survey of Canada) laboratory at Calgary, Alberta, performed the following analyses: (a) liquid chromatography and gas chromatography of 6 condensate samples, (b) bitumen extraction, liquid and gas chromatography of 14 selected source rock samples, and (c) Rock-Eval pyrolysis and TOC content of 135 samples (washed cuttings and cores). The condensate samples were taken from the ISPG sample storage facility at Calgary, Alberta. The work was scheduled to be completed by October 31, 1991 if all the data and samples are available from the ISPG laboratory in due time.

Due to a prolonged strike by Federal Government employees, the analytical work at the ISPG laboratory was delayed substantially. On September 19, 1991, we requested the Scientific Authority of this research project to extend the date of the submission of the final report to December 31, 1991, because the samples for aromatic GC-MS work of the subcontractor (Dr. Michael Kruge, Southern Illinois University at Carbondale, Illinois) were delayed for two months. Our request was accepted by SSC, Dartmouth, Nova Scotia (on October 9, 1991) based on the recommendation of the Scientific Authority.

### ***Scientific Aspect***

During the past twenty years, significant gas and associated condensate or light oil were discovered in the Jurassic-Cretaceous reservoirs around the Sable Subbasin of the Scotian Basin. Since 1976, a number of publications recorded various aspects of organic geochemical studies such as source rock potential and maturation, oil quality, possible migration avenues, and possible oil-oil and oil-source rock correlation (Barss et al., 1980; Bujak et al., 1977; Cassou et al., 1977; Rashid and McAlary, 1977; Powell and Snowdon, 1979; Powell, 1982, 1985; Purcell et al., 1979). Although these studies did little to solve the regional complexity of hydrocarbon source rock questions, they opened up new dimensions of advanced knowledge on source rock and crude oil geochemistry including fluorescence microscopy and aromatic biomarker GC-MS techniques. In spite of these

significant publications on the various light oil/condensate or source rocks, neither the source rocks nor the liquid hydrocarbons have been studied systematically in order to resolve the major problems related to hydrocarbon generation, migration and entrapment. The major issues which still remain unsolved are: (a) the possible source rock types in various stratigraphic intervals; (b) a proper database of organic geochemical properties for various crude oils and condensates; (c) the relation between hydrocarbon generation and overpressuring; and (d) possible oil-oil and oil-condensate-source rock correlation.

The proper evaluation and solution of the existing problems by organic geochemical parameters are extremely important for systematic correlation of discovered liquid and gaseous hydrocarbons and for predicting future prospect zones in the adjoining areas. In 1988, the Basin Analysis Subdivision of the Atlantic Geoscience Centre, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, initiated systematic research projects to characterize and resolve these problems. These studies characterized some of the source rocks in various stratigraphic intervals and characterized the geochemical properties of some selected oils and condensates (Mukhopadhyay and Birk, 1989; Mukhopadhyay, 1989; Mukhopadhyay and Wade, 1990; Mukhopadhyay, 1990a; Mukhopadhyay, 1990b). However, those studies could not complete the geochemical database of most of the important source rocks and condensate/light oil in this region. Moreover, Mukhopadhyay (1990a), from the aromatic biomarkers and isotope analyses, indicated (a) the possible lacustrine origin for the light oils of the Cohasset and Panuke fields, and (b) the origin of various crude oils or condensates from three types of source rocks. This research project was taken up in order to characterize, in detail, the source rocks from the upper and lower Missisauga, Abenaki, Mic Mac, Verrill Canyon and Logan Canyon Formations and to characterize other remaining condensates to develop a composite picture of the organic facies, source rock and light oil/condensates in order to better evaluate the possible oil-oil and oil-source rock correlation.

The objectives of this research are (a) to identify and analyse additional source rock intervals in the Logan Canyon, Missisauga, Mic Mac and Verrill Canyon Formations with particular emphasis on potential lacustrine environments that may have been the source of the Cohasset/Panuke oils, and (b) to correlate the geochemical characteristics of the oils and condensates recovered from wells with the liquid hydrocarbons extracted from source rocks in an attempt to identify the origin of the various oils and condensates discovered on the Scotian Shelf.

The report also incorporates some of the data and interpretations which were generated during 1989-1990 research contracts on Scotian Shelf oil/condensate and source rock samples funded to Global Geoenergy Research Ltd. by SSC, Dartmouth, Nova Scotia at the initiation of the Basin Analysis Subdivision of AGC (BIO), Geological Survey of Canada, Dartmouth, Nova Scotia.

## SAMPLES

A total of 119 unwashed cuttings and 16 core samples from 21 wells were selected after examination of the washed cuttings (at the CNSOPB Repository) and lithologs. The unwashed cuttings were washed through two sieves (10 and 200 mesh). The cuttings and core samples from Alma F-67 and South Desbarres O-76 were thoroughly washed with *Sunlight* detergent and water because these two wells were drilled with oil-base drilling mud (Shell Sol DMS). After washing, only samples of -10 to + 200 mesh size were selected; some of the samples are hand-picked shale cuttings. The depth, stratigraphy and lithology of each sample is listed in Table 1. The location of all the samples (source rocks and crude oil/condensates) are shown in Figure 1

## ANALYTICAL METHODS

For the determination of kerogen type by organic petrography, three types of sample preparation were used: kerogen smear slide, whole rock polished pellet, and kerogen polished pellet. We used incident and transmitted white and blue light excitation. The terminologies used for maceral composition and kerogen type determination are from Stach et al. (1982), Mukhopadhyay et al., (1985), Senftle et al., (1986), Teichmuller (1986), and Mukhopadhyay (1989). Details on source-rock characterization using organic facies are shown in Mukhopadhyay and Wade (1990).

Vitrinite Reflectance was measured using both whole rock and kerogen pellets and Zeiss Axioskop with MPM 21 Controller for MPM 03 Photomultiplier. TAI was measured by transmitted light using the smear slide and Staplin's (1969) scale.

Rock-Eval pyrolysis was carried out on selected washed cuttings, washed/hand-picked cuttings, and from the conventional cores using the Rock-Eval II equipment at the ISPG laboratory at Calgary, Alberta. For details of Rock-Eval instrumentation and evaluation of various parameters, see Espitalie et al. (1985).

Bitumen extraction was performed by the ISPG using Soxhlet for 24 hours with dichloromethane. Liquid chromatography was done using 1:1 silica:alumina column and pentane, pentane+dichloromethane, and methanol as solvent for saturate, aromatics, and heterocomponents. The data on the gas chromatography of the saturate fraction of the source rock extracts were received from the ISPG laboratory at Calgary, Alberta.

The stable carbon isotope of the saturate and aromatic fractions of the oil/condensate/source rock extracts were determined using V. G. Micromass Mass Spectrometer. All values reported here are relative to a PDB (Pee Dee Belemnite) standard.

GC-MS of the aromatic fractions (biomarkers) of 18 samples (7 oil/condensate and 11 source rock extracts) of candidate source rocks (Table 6) were analyzed by a Hewlett Packard 5890A gas chromatograph, coupled with a HP 5970B Mass Selective Detector. Aromatic fractions of the

oil/condensate and source rock extracts were separated by liquid chromatography by using pentane + dichloromethane as solvent (for details see Mukhopadhyay, 1990). The GC was held initially at 100°C for 10 min., then raised to 300°C at 3°/min., where it is held for 5 minutes. A 25 m OV-1 column with 0.2 mm inside diameter and 0.33 micrometer film thickness was employed. The mass spectrometer was run in selective ion monitoring mode, collecting data on the following ions: m/z 91, 156, 162, 168, 169, 170, 176, 182, 184, 192, 196, 198, 202, 206, 212, 216, 220, 228, 230, 231, 242, 252, 253, 256, 268, 282, 296 and 310, which are either the molecular ions of the most common polyaromatic compounds or are principal fragment ions of aromatized biomarkers, such as steroids. Two samples were rerun using full scan mode, to confirm that all principal aromatic peaks were recorded. Quantitations were done on the molecular ions of the compounds of interest, using the selected ion monitoring data and the Hewlett Packard data system.

GC Peak Recognition for aromatic biomarkers: A total of 91 GC-MS peaks representing polyaromatic compounds (Table 7 and Figure 5) were recognized and quantified in each of the 32 samples. The chromatographic character of the peaks are more clearly illustrated on the individual mass chromatograms, exemplified by those of samples NS9101 (Figs. 6-10). As the mass chromatograms show, the polyaromatic peaks are often clusters of isomers, many of which cannot be specifically identified due to the similarity of their mass spectra and the lack of commercially available authentic standards. However, most of the members of each cluster can be separated by GC and the variations in their relative peak distributions from sample to sample can provide much useful empirical information as to maturation levels and organic matter type. The individual peaks are labelled according to their mass spectrometric base peaks, which for all compounds are the molecular ions, except for the triaromatic steroids, and by their order of elution. For example, the six C<sub>2</sub>-alkylnaphthalene peaks, with a molecular ion of m/z 156, are designated peaks 156a through 156f (Fig. 6). Closely eluting peaks, such as the two which comprise peak 156b, were not resolved in all samples and are summed as a single peak for consistency. There are several exceptions to the labelling system, designating (a) unsubstituted polyaromatics such as phenanthrene (PHN) or (b) heteroatomic aromatics which have molecular ions coincident with hydrocarbons, such as dibenzothiophene (DBT), sharing the m/z 184 trace with C<sub>4</sub>-alkylnaphthalenes.

## **SOURCE ROCK CHARACTERIZATION**

### **Total Organic Carbon**

Total organic carbon content of various samples varies between 0.07 to 18.5% (weight percent). However, except for three samples (one from Chebucto K-90 and two samples from N. Triumph G-43), all other samples which have more than 4% TOC are contaminated by drilling mud additives (lignite etc.) and/or cavings. Some of the contaminants remained in the samples even after

hand-picking. None of the core samples contain more than 4% TOC.

There is no correlation between the stratigraphy of the samples and their TOC content. However, most of the samples from the Naskapi Member of Logan Canyon Formation have TOC contents greater than 1%. Compared to other wells, samples from W. Chebucto K-20 and N. Triumph G-43 are rich in TOC having more than 1.5%.

### ***Organic Facies and Kerogen Type by Microscopic Methods***

Table 1 illustrates the maceral composition of 135 samples. Mukhopadhyay and Wade (1990) from the modified concepts of Jones (1987), showed the implication of maceral composition in defining organic facies and source rock potential of a rock. Two other petrographic criteria (fluorescence characteristics and oxidation features) are also used in defining hydrocarbon potential of a rock which also differentiates a source and nonsource rock for liquid and gaseous hydrocarbon generation (Table 2).

According to those petrographic criteria, none of the 135 samples analyzed were originated from a typical anoxic environment. These sediments were deposited in a partially sheltered or open basin as indicated by the absence of >75% amorphous liptinite (I or II or III) or alginite (tel- or lam-), and the presence of minor oxidized framboidal pyrite and coarser clastics (such as quartz grains > 10 micrometer in size).

Most of the samples contain abundant terrestrial organic matter (vitrinite, inertinite, exinite/resinite, and amorphous liptinite III or amorphous OM). Exception are some samples from Alma F-67 (5045m), uncontaminated samples of Olympia A-12 (all samples below 5430m), and most samples from the N. Triumph G-43, W. Chebucto K-20 and Whycocomagh N-90 wells; these samples contain more than 20-25% marine liptinite. Some of the organic-rich samples from S. Desbarres O-76 (3801m), South Sable B-44 (4990m), Penobscot L-30 (13311 ft), Venture H-22 (4965m) and uncontaminated core samples from Thebaud C-74 (3938m) wells show abundance of terrestrial liptinite mixed with some amounts of marine liptinites. Except in some samples from W. Chebucto K-20 and N. Triumph B-52 or G-43 wells, most of terrestrial liptinites (exinite, resinite, and amorphous liptinite III) do not show much fluorescence, even in low maturity, suggesting partial oxidation of these liptinites during transport to marine environment.

Some of the lignite-contaminated cuttings (Olympia A-12, Thebaud C-74, Uniacke G-72, Venture H-22) which have anomalously high TOC contents (>4%), show some abundance of amorphous liptinite II; these liptinites are considered non-indigenous and are possibly derived through cavings. A few of the samples contain non-oxidized marine phytoplanktons such as dinoflagellates (example: Migrant N-20, 7780 ft) and acritarchs (example: Chebucto K-20, 4075m and Demoscota G-32, 9450 ft) which are included with lamalginite. Some rocks from the Cree and

Naskapi Member (Logan Canyon Formation) contain partially oxidized *Botryococcus* algae (telalginite) (example: Demoscota G-32, 7250 and 7350 ft; Penoscot L-30, 6950 ft).

Secondary liptinites (solid bitumen and oil droplets) are common to rare in most source rocks. The most striking examples of large solid bitumen was observed in the samples from Cree E-35, 10300 ft and Chebucto K-20, 5220m. Some of the samples from Thebaud C-74 contain anomalous high contents of solid bitumen which are considered as contamination from drilling mud additives (asphalt). The most striking example of liquid hydrocarbon generation was noted in a sample at 5210m from W. Chebucto K-20 where *oil droplets* (orange fluorescence) are found to be derived from the amorphous liptinite II.

Based on special petrographic criteria and maceral composition, only one sample (Alma F-67, 5045m) is considered as Kerogen Type IIA (60-90% crude oil) and seven samples including Migrant N-20: 14460 ft; N. Triumph G-43: 3695 and 4845m; Olympia A-12: 5430 and 5625m [? contamination]; S. Desbarres O-76:3801m; and W. Chebucto K-20:5210m) are considered as Kerogen Type IIA-IIB (50% oil + 50% condensate of the 60% of liquid hydrocarbons). Only those samples (8 samples total) are considered as possible source rocks for the generation of crude oil reserves. Twenty seven samples are considered as Kerogen Type IIB (50% condensate + 40% gas). Four samples are considered as nonsource for any minor hydrocarbon reservoir. The remaining 96 samples represent Kerogen Types IIB-III and III which produce mainly gas.

### **Rock-Eval Pyrolysis**

The change in amount in mg HC ( $S_2$ ) or  $CO_2$  ( $S_3$ ) /g TOC, as seen in two major Rock-Eval parameters for source rock evaluation, corroborates well with the petrographic data (Table 2). Exceptions are for some samples from the Migrant N-20 (14660 ft) and Olympia A-12 (5430 and 5625m) wells which contain more liptinite macerals than indicated by its corresponding hydrogen index values. Figures 2a through 2u show plots of hydrogen index ( $S_2/TOC \times 100$ ) versus oxygen index ( $S_3/TOC \times 100$ ). Accordingly, (a) one sample from the Alma F-67 well lies on Kerogen Type II trend, (b) one sample from S. Desbarres O-76 (3801.7m) lies close to the Kerogen Type I and II trend, (c) both samples from N. Triumph lie near the Kerogen Type II trend, (d) several samples from Migrant N-20 and N-Triumph B-52 and most samples W. Chebucto K-20 lie between the Kerogen Type II and III trend, and (e) most other samples from various wells lie either close to, or below the Kerogen Type III maturation path. These results again suggest that only a few samples are capable of producing crude oil, a fair number of the samples are condensate-prone rather than crude oil-prone source rocks, and the majority of samples are gas-prone source rocks.

Production index ( $S_1/S_1 + S_2$ ) (PI) is considered as a parameter to check either the presence of allochthonous bitumen or the amount of redistributed liquid hydrocarbons (generated by the



cracking of kerogens) by primary migration. Except in a few samples (example: S. Desbarres O-76, 3801m: PI = 0.07), the vast majority of the samples show anomalously high production indices (0.10 to 0.72) suggesting the presence of mostly redistributed bitumen in most of the non-contaminated samples. Anomalously high PI (>0.2) in non-contaminated samples at shallower depths and lower maturity (example: samples from Penobscot L-30 and Migrant N-20) indicate the presence of allochthonous migratory hydrocarbons. The PI increases gradually from 0.10 at 3938m through 0.39 at 4990m to 0.45 at 5220m in well South Sable B-44 which suggests the generation of crude oil-like bitumen due to cracking of kerogens by progressively advanced maturity.

### **Maturation by Vitrinite Reflectance, TAI, and $T_{max}$**

Table 2 shows the vitrinite reflectance, TAI (Thermal Alteration Index) and  $T_{max}$  (°C) of the analyzed samples. Most of the wells show a uniform increase in vitrinite reflectance according to depth (example: South Sable B-44). Accordingly, the onset of the *oil window* (0.5%  $R_o$ ) in various boreholes is between 2600 and 3100m, the *peak hydrocarbon generation* (0.8%  $R_o$ ) is between 4000 and 4500m and the end of *oil window* (1.4%  $R_o$ ) is around 5500 and 5800m. The vitrinite reflectance data suggest that rocks from the Cohasset/Panuke/Sable Island wells show higher maturity than those from wells in adjacent areas of Sable Subbasin at the same depth level.

Uncontaminated samples show good correlation between vitrinite reflectance, TAI and  $T_{max}$  values (according to Espitalie et al., 1985; Mukhopadhyay, in press): as an example in Cree E-35 well at 12980 ft the  $R_o$  is 0.70, TAI is 2<sup>+</sup> and  $T_{max}$  is 445. In some cases, the reflectance value does not correlate with the TAI and  $T_{max}$  values; for example, the sample at 14660 ft from the Migrant N-20 well where  $R_o$  is 0.79%, TAI is 3<sup>-</sup> (shows higher maturity than  $R_o$ ) and  $T_{max}$  is 431 (shows lower maturity than  $R_o$  which is possibly caused by the presence of abundant allochthonous bitumen which suppresses both the reflectance and  $T_{max}$  values. The highest vitrinite reflectance (1.7%  $R_o$ ) was observed in S. Desbarres O-76 at 5957.2m (core sample) which has a corresponding  $T_{max}$  value of 559°C and a TAI value of 3<sup>+</sup> and the lowest vitrinite reflectance is observed in Sable Island O-47 at 6229.5 ft which has a  $T_{max}$  value of 427 and a TAI value of 1<sup>-</sup>. Contaminated samples have very low  $T_{max}$  values.

### **Source-Rock Potential**

Comparing maceral composition and organic facies, hydrogen and oxygen indices (in Rock-Eval pyrolysis) and maturation parameters, the following on source rock potential can be made based on the analytical data presently on hand:

Multiple source rocks are present in various stratigraphic levels. Oil-prone source rocks are rare in the shelf area. 59.3% of the source rocks can generate only gaseous hydrocarbons, 11.9%

can generate mainly gas and minor condensate, 20.0% will generate mainly condensate and minor gas, 5.2% of the source rock can generate equal amounts of crude oil and condensate with minor gas, and only 0.7% of the source rocks are typical oil-source rock. Comparing the percentages of nonsource (3%), gas/condensate-bearing source rock (31.9%), and gas-bearing (59.3) and low maturity trend of the basin, more deep gas or gas/condensate-bearing reservoirs are to be expected in currently unexplored areas of the Scotian Basin.

## **GENESIS OF LIQUID HYDROCARBONS AND OIL-SOURCE CORRELATION**

### ***Liquid and Gas Chromatography of Crude Oil/Condensates and Source-Rock Extracts***

The gross composition of most of the analyzed samples used for aromatic GC-MS studies was included in our earlier report (Mukhopadhyay, 1990b). Only data from one sample (Bluenose 2G-47) is available this year from the ISPG, Calgary. The low saturate /aromatic ratio closely resembles those of the condensate samples of Chebucto K-90, Banquereau C-21 and N. Triumph B-52 (Table 3).

The *liquid chromatography* data of 13 source rock extracts indicated two distinct groups of liquid hydrocarbons (Table 3). One group has anomalously high saturate content (example: N. Triumph G-43, W. Chebucto K-20 etc.) and the other contains high NSO and asphaltenes and low saturate (example: Cree E-35, Migrant N-20, S. Sable B-44 etc.). Samples from S. Desbarres O-76 and Penobscot L-30 contain a higher percentage of aromatic hydrocarbons (>10%).

Figures 3a through 3n show *gas chromatograms* of the saturate fraction of some of the selected source rock extracts. The chromatograms show a diverse distribution pattern of normal and other alkanes and a wide range of the pristane/phytane ratios. The n-alkane distribution of the sample (5045m) from the Alma F-67 well, shows a close similarity with the chromatograms displayed by one base oil (Shell Sol DMS) which was used during drilling with oil-base mud system (Mukhopadhyay, 1990c). This suggests that the sample is contaminated with the base oil during drilling which could not be cleaned even after washing with the detergent. The sample was, therefore, not considered for further interpretation. According to the similarity of the n-alkane distribution pattern and pristane/phytane ratios, the source rock extracts are grouped into four categories. The first group of samples include N-Triumph B-52 (3660m), N. Triumph G-43 (3695m and 4845m), Migrant N-20 (11770 ft), W. Chebucto K-20 (3345m and 5210m). These samples show low pristane/phytane ratio (<1.3) and the dominance (>80%) of low-molecular-weight (<C<sub>20</sub>) compounds. Those bitumens were possibly derived from the macerals like alginite (both lam- and tel-) and alginite-related amorphous liptinite 2 (Tissot and Welte, 1984; Mukhopadhyay et al., 1985) possibly of marine origin. The second group of samples include S. Desbarres O-76 (3801.7m), South Sable B-44 (3938m), Thebaud C-74 (3911m) and Venture B-52 (5121m). These samples show high

pristane/phytane ratio ( $>2.0$ ) and the dominance of high-molecular-weight ( $>C_{20}$ ) compounds. The bimodal distribution of the n-alkane patterns and those other parameters mentioned before, suggest a mixed origin of those hydrocarbons; hydrocarbons  $<C_{20}$  are derived from the macerals like alginite and amorphous liptinite 2 whereas hydrocarbons  $>C_{20}$  are derived from the wax-rich macerals like cutinite, suberinite, and sporinite or amorphous liptinite 2 (biodegraded macerals derived from the exinite). The third group include one sample from Penobscot L-30 (6950 ft). It has comparatively lower pristane/phytane ratio than the second group. The sample shows abundance of branched and cycloalkanes with three prominent humps around  $C_{16}$ ,  $C_{20}$ , and  $C_{27}$  to  $C_{30}$  regions. The abundance of possible terpenoid (Sesqui-, di- and tri-) compounds indicates that this bitumen is possibly derived from the maceral resinite or resinite-derived amorphous liptinite 3 or liptodetrinite (Tissot and Welte, 1984; Mukhopadhyay, 1989). The fourth group includes two samples from the Cree E-35 (10960 ft) and Whycocomagh N-90 (3310m) wells. The n-alkane distribution pattern of these samples suggests close similarity with the first group of samples; both contain dominant low-molecular-weight alkanes. Higher pristane/phytane ratio of these samples compared to the samples from the first group indicates lower maturity than those samples or presence of allochthonous bitumen in those samples.

#### ***Stable Carbon Isotope of Saturate and Aromatic Fractions***

Stable carbon isotopes have been widely used as a tool for oil-oil and oil-source rock correlation (Tissot and Welte, 1984; Sofer, 1984; Sofer et al., 1986). Tables 5a and 5b show the stable carbon isotope data of the saturate and aromatic fractions of the light oil/condensate and source-rock extracts. These data are plotted in the Figures 4a and 4b. The dividing line drawn in Figure 4a and 4b is from the linear equation evolved by Sofer (1984) to distinguish between waxy (terrestrial) and nonwaxy (marine) oils, which is as follows:

$$\delta^{13}C_{aro} = 1.14 \delta^{13}C_{sat} + 5.46.$$

Figure 4b plotted the isotopic data only from the analyzed light oil and condensate samples. The best-fit linear equation for these samples is as follows:

$$\delta^{13}C_{aro} = 1.078 \delta^{13}C_{sat} + 3.54$$

Sofer (1984) from the "Y" intercept defined two distinct linear equations, one for waxy (terrestrial) and another for nonwaxy (marine) crude oils. The best-fit linear equation from the Scotian Shelf light oil and condensate samples (Fig. 4b) is very close to the nonwaxy oils as defined by Sofer (1984).

The position of the samples in Figure 4a and 4b shows a broad variation of isotopic composition between -29‰ to -26‰ for the saturate fraction and between -28‰ and -23‰ for the aromatic fraction. One of the four condensate samples (Arcadia J-16, DST #5) is clustered along with the Group 2 oil/condensate Family (Mukhopadhyay, 1990b). Sofer (personal communication, 1990) suggested that maturation trend points towards the positive part of the isotope data. Accordingly, Arcadia J-16 condensate has the highest maturity among the four analyzed samples of 1991; Bluenose 2G-47 and Penobscot L-30 condensates are the least mature while Venture H-22 condensate lies in between.

Six source rock extracts (k, o, n, r, s, q of Table 5) out of thirteen samples analyzed in 1991, plotted far away from position of most of the crude oil/condensate samples and lie deep within the *terrestrial* region of Sofer (1984) (Figure 4a). Another five samples (l, p, u, v, w of Table 5), although lie very close to the dividing line of *terrestrial* and *marine* region of Sofer (1984), are plotted further away within the so-called low mature zone of Sofer (personal communication, 1990). Only two samples (m and t) plotted close the Group 1 crude oil and condensate samples. According to the isotopic data and plot of the source rock extracts, only one sample (Venture B-52, 5121m) is considered as correlatable with crude oil and condensate samples of the Group 1.

### ***Biological Markers: Aromatic Hydrocarbons***

#### **Data Handling**

Due to the great number of chromatograms generated from this large data set, visual comparisons were not sufficiently thorough for petroleum-to-petroleum or petroleum-to-rock correlation. A multivariate statistical approach was chosen as the most effective. Once the raw integrated areas of the 91 peaks were transferred to a minicomputer spreadsheet, they could be normalized to the largest peak in the sample and plotted in "bar graph" format (Fig. 11a), which is a clearer representation of the data than the complex total ion chromatogram (Fig. 5). Since the variation in peak intensities is so wide, the representation can be further clarified taking the base 10 logarithm of the normalized peak intensities (Fig. 11b), in which the tallest peak (110%) now has a value of 2 and very small or missing peaks (with normalized areas of 0.01%) are assigned values of -2.

To be able to better recognize variations from sample to sample within compound classes, such as the phenanthrenes, the peak areas were normalized again, this time according to compound class as follows: (1) C<sub>2</sub>-alkylnaphthalenes (m/z 156), (2) C<sub>3</sub> and C<sub>4</sub>-alkylnaphthalenes (m/z 170 and 184), (3) bes-, mono- and dimethyldibenzothiophenes (m/z 184, 198, and 212), (4) dimethylbiphenyls and isomers (m/z 182), (5) methyldibenzofurans (also m/z 184), (6) des-, mono-, and dimethylphenanthrenes (m/z 178, 192 and 206), (7) des-, mono- and dimethylpyrenes and

fluoranthenes (m/z 202, 216 and 230), (8) des- and monomethylchrysenes and isomers (m/z 228 and 242), (9) benzo[alpha]pyrene and isomers (m/z 252), and (10) C<sub>26</sub> - C<sub>28</sub> triaromatic steroids (m/z 231). The C<sub>2</sub>-alkylnaphthalenes were grouped separately from the other alkylnaphthalenes to avoid the introduction of bias, since the rock extracts suffered partial evaporative losses of such light compounds during sample preparation. An example of a plot of the base 10 logarithms of group-normalized peak areas is shown in Figure 11c. The various compound classes are delineated by the bar patterns and by labels.

The variations among samples in plots such as Figure 11c are functions of both maturation and organic matter type. To begin to separate these two effects, methylphenanthrene indices (MPI) were calculated for each sample, using the formula (Radke and Welte, 1983):

$$1.5 (3\text{-mPH} + 2\text{-mPH})$$

$$\text{-----}$$

$$(\text{Phenanthrene} + 9\text{-mPH} + 1\text{-mPH})$$

or in terms of the notation used in this study:

$$1.5 (192a + 192b)$$

$$\text{-----}$$

$$(\text{PHN} + 192c + 192d)$$

The samples were arranged in order of increasing MPI and three groupings became apparent: 8 samples with MPI ≤ 0.62, 5 samples with MPI ≥ 1.00, and a large intermediate group. The base 10 logarithms of the areas (normalized by compound class) of each of the 91 peaks in the low MPI sample set were averaged, as were those with high MPI values, forming composite low and high maturity data sets. Averages were employed to cancel differences associated with organic matter type. The low MPI averaged data were subtracted from the high and the differences reported as *a* in Table 7. Where *a* has a large positive value, the corresponding peak increases greatly with maturation within the compound class, while a large negative value indicates that the peak decreases markedly in concentration as maturity increases. A variety of maturation indices constructed using these peaks are considered in the Results and Discussion section. Values of *a* range widely, from -2.62 to +0.87. A subset of data was extracted comprising those 51 peaks falling within a narrow window where *a* ≤ 0.2, to dampen the effects of maturation. "Maturation-sensitive" peaks, i.e., those outside the window, are designated by a "+" or "-" in Table 7, respectively indicating their tendency to increase or decrease with maturation. Next, the average peak areas and their standard deviations were computed for all 91 peaks of all 32 samples (log<sub>10</sub>, normalized by class). The standard deviations range from 0.02 to 1.73 (Table 7). To eliminate the peaks showing little variation (and thus little potential to add in correlation), the subset of 51 maturation-insensitive peaks were further reduced to those 31 peaks with standard deviations > 0.14. To confirm that

maturation effects were indeed dampened, each of the 31 peaks of the latest subset were averaged for the 8 low MPI and for the 5 high MPI samples. When these two average sets were co-plotted, they matched closely, indicating that there is little residual maturity effect.

Upon examination of the values of the 31 peaks in all samples, it was found that two peaks (230e and 230f) had very low values in a few samples. To avoid distortion in the correlations that would be caused by these few outliers, the two peaks were eliminated, reducing the final correlation set to 29 peaks. These are marked with a "\*" in Table 7. As an example, the correlation set for sample NS9101 is plotted in Figure 12. Even with the original data set scaled logarithmically, normalized among compound classes, and reduced from 91 to 29 peaks, visual correlation among 32 samples is inefficient and merely qualitative. It can be seen by co-plotting that samples NS9115 is very much like NS9006, but both differ from NS9012 (Figures 13a, 13b). This can also be expressed graphically by cross plotting NS9115 and NS9006, producing a tight linear distribution, and with NS 9012, resulting in a scattered cloud of points, only vaguely linear (Figs. 13c and 13d). These results can be expressed quantitatively using coefficients of determination ( $r^2$ ) from the linear regression of any two samples, where  $r^2$  varies from 0 to 1, with a value of 1 indicating a perfect match. With the assistance of a computer, over 500  $r^2$  values were determined for all possible pairings of the 32 samples (Table 8).

To aid in the interpretation of these results for the oil-oil and oil-source correlation exercise, a cluster analysis was undertaken. The single linkage method (Massart and Kaufman, 1983) was applied to the correlation matrix of Table 8. Briefly, the clustering is begun by choosing the best match from the correlation matrix and linking those two samples on a dendogram (Figure 14), with the length of the connecting branches scaled to the  $r^2$  value. Thus, the closer the branch, the better the match. Then, the next closest match is plotted and matching continues until all samples are included. If a match was to a sample which had already been incorporated into a cluster, then the new sample is directly linked to that cluster on the dendogram. Any subsequent match of that new sample to another member of the original cluster is bypassed. In this manner, the dendogram forms a network of "nearest matches" - the best correlation of a sample with any member of a pre-existing cluster determines the quality of the match to the cluster as a whole.

#### Maturity Determination

Aromatic maturity parameters, including the methylphenanthrene index (MPI, Radke and Welte, 1983), the ratio of triaromatic to monoaromatic steroids, and the ratio of low to high molecular weight triaromatic steroids (Mackenzie et al., 1983), are commonly applied in evaluating oils and source rock extracts. Since the present study was limited to the analysis of aromatic

fractions, in part due to the lack of saturate biomarkers, it was expected at the outset, that maturation determinations could be successfully made. After analysis it became apparent that the monoaromatic steroid were weak or not present in the sample set. Thus the two parameters employing steroids were at their maximum values in most cases, suggesting that the overall maturity level for the sample set was rather high. This is not surprising, given the burial depth of many of the samples (Table 6). Although the MPI was originally calibrated on terrestrial organic matter and the types of organic matter represented in this study were unknown at the outset, the author has observed that the MPI can be a useful relative indicator of high levels of maturity (mid to late oil window) for many types of organic matter. It was thus decided to begin maturation ranking of the samples by using the MPI.

MPI values for the 32 samples range from 0.46 to 1.25, with the majority of samples (19) falling between 0.68 and 0.87 (Figure 15). Not wishing to depend completely on a sole maturity parameter, it was expected that additional maturation indicators could be created from polyaromatic peaks other than methylphenanthrenes. For purposes of this study, maturation variations are limited to changes in relative concentration among the members of a compound class, as defined in the Methods section. Additional maturity parameters might also be created, by mixing peaks from different compound classes, but the possibility was not investigated here.

To test the maturation sensitivity of all the peaks in the data set ( $\log_{10}$ , normalized with compound classes), those samples with the lowest and highest MPI values were segregated. The group of eight low maturity samples ( $\text{MPI} \leq 0.62$ ) consists of seven extracts and one condensate. Three oils and two extracts comprise the high maturity group ( $\text{MPI} \geq 1.00$ ). By using only these two extreme samples, there is a high confidence level that collective differences between two groups do in fact represent maturation effects. Furthermore, by using averages, many of the differences due to organic matter type will be dampened. After subtraction of the low MPI averages from the high, the extent of maturation susceptibility for each peak is quantified by the difference,  $\Delta$  (Table 7). Several of the peaks particularly sensitive to maturation effects (marked with "+" or "-" in Table 7, denoting the tendency to increase or decrease) were selected to form additional maturity ratios as follows:

$$\begin{aligned} & \text{C}_3\text{-Alkyl-naphthalene Index} = \frac{(170c + 170f)}{(170c + 170f + 170h) + (184a + 184b + 184e)} \\ & \text{C}_4\text{-Alkyl-naphthalene Index} = \frac{(184a + 184b + 184e + 184d + 184i)}{206c} \\ & \text{Dimethylphenanthrene Index} = \frac{(206c)}{(206c + 206d + 206e)} \end{aligned}$$

$$\text{Chrysene Index} = \frac{(206c + 206l) \text{ CHR}}{\text{CHR} + \text{BAN}}$$

They are all expressed in the format:

$$\frac{\text{"peaks which increase"}}{\text{"peaks which increase" + "peaks which decrease"}}$$

so that the ratios increase with maturity and all can only vary between 0 and 1.

To determine a more solid maturity ranking than could be done with MPI alone, (recast as a ratio in the above format) and the four ratios just described were all scaled so that their lowest values were set to 0.0, their highest to 1.0 and the rest distributed proportionately. The scaled parameters were averaged and the samples sorted by this average. Figure 15 displays the five maturity ratios (unscaled, original form), with the samples arrayed accordingly. Although noise is present in each case, each curve progressively increases and thus the overall maturation ranking is clear. There is a lower maturity group, comprised of the first 7 or 8 samples (NS9011, NS9111, NS9107, NS9112, NS9106, NS9101, NS9105 and possibly NS9004). It must be remembered that "low" here means only relatively low: most of the group is undoubtedly at least in the early oil window. A high maturity group of the last 5 or 6 samples includes NS9008, NS9116, NS9102, NS9117, NS9115, and NS9014. The large middle group of samples in most case show little variation in any of the maturity parameters, so they may be considered to be at about the same intermediate level.

#### Oil-Oil and Oil-Source Rock Correlation

A subset of aromatic peaks was chosen for correlation purposes by the elimination of peaks strongly susceptible to maturation and of those peaks which showed little variation under any circumstances, as described in the methods section. The data had been normalized according to compound class and scaled logarithmically prior to the filtering process. There may be some residual maturation effects in the correlation subset, but they should be minimal.

Upon examination of the matrix of coefficients of determination (8), it can be seen in the left-most column, corresponding to oil sample NS9001, that the quality of matches varies considerably. There are many close matches ( $r^2 > 0.9$ ), such as those with oils NS9006, NS9007, NS9008, NS9010, NS9115, NS9116 and NS9117. It is extremely likely that these oils are genetically related. The



matching is of high quality in spite of the fact that four of the oils (NS9008, NS9115, NS9116 and NS9117) are highly mature, indicating that the correlation functions across maturity boundaries. The similarity of the four oils of the NS90-series was recognized in the preliminary study (Mukhopadhyay, 1990b); the present study covers a larger sample set, having added NS91-series.

Further persual of Table 3 leads to the recognition of close cross-matching among the oils listed above, as well as additional close relations with other oils and several rock extracts. Several other smaller groupings also become apparent. Many other samples appear quite unrelated. To present this graphically in a concise and quantitative manner, a cluster analysis was performed and the results drawn as a dendrogram, scaled to  $r^2$  values (Figure 14). Since the clustering was done by the single linkage method, which joins clusters by linking the nearest neighbours, the values of  $r^2$  in Figure 14 are all high ( $> 0.75$ ), whereas in Table 3, the poorest linkage is 0.24. Therefore, only the very best matches on the dendrogram (say,  $r^2 > 0.9$ ) should be taken to indicate a genetic relationship.

The dendrogram confirms that the 8 oils just discussed form a tightly knit group, with all linkages above 0.95. A second tier of closely related samples (linkage above 0.90) consisting of oils NS9118 and NS9009 and, most interestingly, rock extracts NS9102 and NS9110. Rock extract NS9107 is not far behind, linking at 0.89. It is thus postulated that the first two, and probably the third, rocks may be sources for the oils in this first large grouping. However, since sample NS9110, from the well Thebaud C-74, is only 23 m below the zone sampled by DST#9 in that well (NS9118), it may actually be migrated petroleum, rather than bitumen in a source rock. In any case, the stratigraphic position, depositional environment, and lithological and organic petrological character of all three rocks should be evaluated to test the source rock hypothesis.

A grouping among rock extracts NS9104, NS9106, NS9014, NS9013, and NS9108 is manifested in Figure 14, with the latter two extracts especially similar and the two are, in fact, from the same well (Alma F-67). These rocks are linked only distantly to any of the oils in the study and thus cannot be considered to be oil sources by the criteria used here. It would be interesting to check to see if these rocks are from the same or similar stratigraphic units. A very close, but isolated pairing of extracts NS9103 and NS9109 is also evident. These two samples are from the same wells (N. Triumph G-43), although they are separated by a vertical distance of over 1100m (Table 6). Three additional isolated pairings of fairly low quality are also noted: extract NS9112 and NS9113, oils NS9002 and NS9003, and extract NS 9011 and NS9105. These two oils, along with NS9004 and NS9005, were grouped together in the preliminary study (Mukhopadhyay, 1990b), but Table 7 and Figure 14 indicates that this grouping is looser than that which binds the majority of oils discussed above. Also the data do not show a reasonable matches of this second class of oils with any of the rock extracts.

Since the presence of organic sulfur in fossil fuel sample is stringly related to the

depositional environment of the original organic matter, it is interesting to examine sulfur content in the samples. Sulfur compounds (dimethyldibenzothiophenes) were important in the cluster analysis, however only variations in their relative concentration within the dibenzothiophene class were considered. A parameter which describes the samples sulfur content was established as the ratio of the sum of all thiophenic compounds to the sum of all phenanthrene homologues and isomers, in the notation of this study:

$$\frac{\text{DBT} + 198 + 212}{\text{PHN} + 192 + 206}$$

this ratio should be more reliable than the one used in the preliminary study, which used only DBT as its thiophenic component.

Values of this ratio are plotted in Figure 16, with samples arranged in the same order as in Figure 14, so that the results may be easily compared. A group with markedly higher thiophene contents is apparent in the lower portion of the diagram, ranging from sample NS9101 down to NS9012. These are all rock extracts, many of which were shown through cluster analysis to be related to one another, but not to any of the oils. With the possible exception of extracts NS9011, with its somewhat lower sulfur content, the thiophene ratio clearly supports this aspect of the cluster analysis. All oils in the study have low thiophene ratios, so the two groupings indicated by the cluster analysis are not distinguished by sulfur content. Interestingly, three candidate source rocks for the first oil family (NS9102, NS9110 and NS9107) all have sulfur content on par with the oils, supporting the conclusions of the cluster analysis.

It is tempting to ascribe the highly thiophenic extracts (NS9101, NS9104, NS9106, NS9014, NS9013, NS9108, NS9103, NS9109, NS9105 and NS9012) to marine rocks and the remainder, including the three postulated oil sources, to non-marine.

## SUMMARY AND CONCLUSIONS

### *Source Rock Characterization*

According to maceral composition and organic facies, hydrogen and oxygen indices (from Rock-Eval pyrolysis) and analysis of various maturation parameters ( $R_o$ , TAI and  $T_{max}$ ) of 135 samples, it is evident that multiple source rocks (Kerogen Types IIA, IIA-IIB, IIB, IIB-III, III-IV) are present in various stratigraphic levels. 59.3% of the sampled source rocks can generate only gaseous hydrocarbons, 11.9% can generate mainly gas with minor condensate, 20.0% will generate mainly condensate and minor gas, 5.2% of source rocks can generate equal amounts of crude oil and condensate with minor gas and only 0.7% of the source rocks are typical oil-source. Oil prone source

rocks are rare in the studied area. Comparing the percentages of nonsource (3%), gas-bearing (59.3%), and gas/condensate-bearing source rocks (31.9%) and the low maturity trend of the basin, more deep gas or gas/condensate-bearing reservoirs are expected in currently unexplored areas of the Scotian Shelf.

### ***Genesis of Petroleum and Oil-Source Correlation***

The great majority of crude oil/condensates and rock extracts in this study are at advanced levels of thermal maturity (middle to late oil window), as indicated by values of the Methylphenanthrene, Dimethylphenanthrene, Chrysene, C<sub>3</sub>-Alkyl-naphthalene and C<sub>4</sub>-Alkyl-naphthalene Indices. This is not surprising, giving the great burial depth of many of the samples.

By comparing the relative abundance of polyaromatic compounds in the highest and lowest maturity samples, it was possible to choose a subset of peaks showing little variation with maturity. The distributions of these maturation-insensitive peaks could then be evaluated statistically, isolating variations due to organic matter type.

Multiple linear regression and subsequent cluster analysis of aromatic GC-MS parameters reveals a closely related family of oils including oils from the wells Chebucto K-90, N. Triumph B-52, Olympia A-12, S. Venture O-59 (two samples), Glenelg J-48, Bluenose 2G-47, Arcadia J-16, Venture H-22 and Thebaud C-74. A second oil family, whose members are less closely related than the first, includes light oil from Cohasset D-42 and A-52, Panuke B-90 and Sable Island 3H-58. Isotope data of saturate and aromatic fraction of the extracts do not reveal any clear groupings of these two oil families.

Three rock extracts, from the wells Venture B-52 (5121m), Thebaud C-74 (3911m) and S. Desbarres O-76 (3861m), match the first group of light oil/condensates, according to the cluster analysis. These should be evaluated as potential source rocks for those liquid hydrocarbons. These extracts also show close similarity in n-alkane distribution pattern and isotope data. These extracts are derived mainly from the terrestrial exinite which were redeposited in a marine environment.

A second group of rock extracts, from wells Alma F-67 (two samples), S. Venture O-59, W. Chebucto K-20 and Whycomomagh N-90 correlate well with each other, according to the cluster analysis, but do not match any of the light oil/condensates. Some of these extracts (W. Chebucto K-20 and Whycomomagh N-90) also show close similarity in n-alkane distribution pattern and isotope data. Organic petrography revealed that marine macerals are common in these samples which corroborate the thiophene as discussed later.

To supplement the cluster analysis, a parameter related to the sulfur content of the biomarkers (the ratio of the sum of all thiophenes to the sum of all phenanthrenes) was established.

It supports the statistical findings, further indicating that most samples have similarly low thiophenic sulfur content, except for the second group of rock extracts outlined above, as well as extracts from wells N. Triumph G-43 (two samples), Penobscot L-30 and Cohasset A-52. From the aromatic biomarker data, it can be tentatively concluded from sulfur contents that these latter samples are derived from marine rocks, while the remainder may be of nonmarine origin.

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## **REFERENCES**

- Alexander, R., Kagi, R. I., and Sheppard, P. N. 1983. Relative abundance of dimethylnaphthalene isomers in crude oils. *Jour. Chrom.* v. 267, p. 367-372
- Alexander, R., Cumbers, K. M. and Kagi, R. I. 1986. Alkylbiphenyls in ancient sediments and petroleums. *Org. Geochem.* v. 10 (1-3), p. 841-845.
- Barss, M. S., Bujak, J. P., Wade, J. A., and Williams, G. L., 1980, Age, stratigraphy, organic matter type and color, and hydrocarbon occurrences in forty-seven wells offshore eastern Canada. *Geo. Surv. Can. Open File Report 714*; 6p.
- Budzinski, H., Garrigues, P., Connan, J., Lee, M. L., Anderson, J., and Bellocq, J. 1991, Determination of maturity indicators in alkylated aromatic series by gas chromatography-mass spectrometry (GC-MS). In Manning, D. A. C. (ed.), *Organic Geochemistry: Advances and Applications in the Natural Environment*, Manchester University Press, Manchester, p. 619-623.

Bujak, J. P., Barss, M. S., and Williams, G. L. 1977. Offshore eastern Canada - Part I and II: Organic type and color and hydrocarbon potential, *Oil and Gas Journal*, v. 75 (15), p. 96-100 and p. 198-202.

Cassou, A. M. Connan, J., and Borthault, B., 1977. Relationships between maturation of organic matter and geothermal effect, as exemplified in Canadian East Coast Offshore wells. *Bull. Can. Pet. Geol.* v. 25, p. 174-194.

Espitalie, J., Deroo, Cr., and Marquis, F. 1985. Rock-Eval pyrolysis and its applications. Report Institut Francais du Petrole No. 33878, 72 p.

Garrigues, P., De Sury, R., Angelin, M. L., Bellocq, J., Oudin, J. L. and Ewald, M. 1988. Relation of methylated aromatic hydrocarbon distribution pattern to the maturity of organic matter in ancient sediments from the Mahakam Delta. *Geochimica Cosmochimica Acta*, v. 52, p. 375-384.

Jones, R. W. 1987. Application of organic facies for hydrocarbon potential. In. *Advances in Petroleum Geochemistry* (Brooks, J., ed.)v. 2, p. 1-90.

Kruege, M. A., Bensley, D. F., and Crelling, J. C. 1989. An organic geochemical and petrologic study of a suite of sporinite-rich coals from the Lower Kittanning Seam, Upper Carboniferous, USA. *Int. Conf. Coal Formation, Occurrence and Related Properties*, Orleans, Abs. no. 9.

Kruege, M. A. Bensley, D. F. and Adams, J. P. 1990a. Comparison of the behavior of molecular maturity parameters in coal and marine shale extracts. 199th American Chemical Society National Meeting, Boston, Div. of Geochemistry. Abs. no. 10.

Kruege, M. A., Crelling, J. C., Pascone, J. M., Palmer, S. R. and Hippo, E. J. 1990b. Confined pyrolysis of Illinois Basin coals and maceral concentrates. 200th American Chemical Society National Meeting, Washington, D. C. Divn. of Geochemistry. Abs. No. 43.

Later, D. W., Lee, M. L., Bartle, K. D., Kong, R. C. and Vassilaros, D. L. 1981. Chemical class separation and characterization of organic compounds in synthetic fuels. *Anal. Chem.*, v. 53: p. 1612-1620.

Lorenz, J. C. (1988) *Triassic-Jurassic Rift-Basin Sedimentology: History and Methods*. Van Nostrand,

New York.

Mackenzie, A. S., Disko, U., and Rullkotter, J. 1983. Determination of hydrocarbon distributions in oils and sediment extracts by gas chromatography-high resolution mass spectrometry. *Organic Geochemistry*, v. 5, p. 57-63.

Massart, D. L., and Kaufman, L. 1983. *The Interpretation of Analytical Chemical Data by the Use of Cluster Analysis*. John Wiley and Sons, New York, 237 p.

Mukhopadhyay, P. K. 1990a. Characterization and maturation of selected oil and condensate samples and correlation with source beds, Scotian Shelf. SSC Report No. OSC90-00245-(014). Contract No. 23420-0-c070/01-OSC.

Mukhopadhyay, P. K. 1990b. Evaluation of organic facies of the Verrill Canyon Formation, Sable Subbasin, Scotian Shelf, SSC Report No. OSC89-00482-(010).

Mukhopadhyay, P. K. 1990c. Oil-base drilling mud research - Phase II. SSC Report. SSC File No. XSG89-00208-(605).

Mukhopadhyay, P. K. and Wade, J. A. 1990. Organic facies and maturation of sediments from the three Scotian Shelf Wells. *Bull. Can. Petrol. Geol.* v. 38 (4).  
p. 407-424.

Mukhopadhyay, P. K. 1989. Characterization of amorphous and other organic matter types by microscopy and pyrolysis-gas chromatography. *Org. Geochem.* v. 14 (3), p. 269-284.

Mukhopadhyay, P. K. and Birk, D. 1989. Organic facies in the Sable Subbasin, Scotian Shelf. *Geo. Surv. Canada*, Open File # 2027.

Mukhopadhyay, P. K. 1989. Cretaceous organic facies and oil occurrence, Scotian Shelf. SSC Report No. OSC89-00136-(008)

Mukhopadhyay, P. K. Hagemann, H. W., and Gormly, J. R. 1985. Characterization of kerogens as seen under the aspect of maturation and hydrocarbon generation. *Erdol und Kohle-Erdgas-Petrochemie*, v. 38 (1), p. 7-18.

Nantais, P. T. 1983. A reappraisal of the regional hydrocarbon potential of the Scotian Shelf. Geological Survey of Canada Open File Report No. 1175, 76 p.

Powell, T. G. 1985. Paleogeographic implications for the distribution of upper Jurassic source beds: Offshore Eastern Canada, Bull. Can. Petrol. Geol. v. 33 (1), p. 116-119.

Powell, T. G. 1982. Petroleum geochemistry of Verrill Canyon Formation, a source for Scotian Shelf hydrocarbons. Bull. Can. Petrol. Geol. v. 30. (2), p. 167-179.

Powell, T. G., and Snowdon, L. R. 1979. Geochemistry of crude oils and condensates from the Scotian Basin, Offshore Eastern Canada. Bull. Can. Petrol. Geol. v. 27 (4), p. 453-466.

Purcell, L. P., Rashid, M. A., and Hardy, I. A. 1979. Geochemical characteristics of sedimentary rocks in Scotian Basin. Bull. Amer. Assoc. Petrol. Geol., v. 63 (1), p. 87-105.

Radke, M. 1988. Application of aromatic compounds as maturity indicators in source rocks and crude oils. Mar. Petrol. Geol. v. 5. p. 224-236.

Radke, M. 1987. Organic Geochemistry of aromatic hydrocarbons. In Brooks, J. and Welte, D. H. (eds.), Advances in Petroleum Geochemistry, v. 2, p. 141-207, Academic Press, London.

Radke, M., Schaefer, R. G., Leythaeuser, D., and Teichmuller, M. 1980. Composition of soluble organic matter in coals: relation to rank and liptinite fluorescence. Geochim. Cosmochim. Acta, v. 44, p. 1787-1800.

Radke, M., Welte, D. H., and Willsch, H. 1986. Maturity parameters based on aromatic hydrocarbons: influence of organic matter type. Org. Geochem. v. 10 (103), p. 51-63.

Radke, M., Leythaeuser, D., and Teichmuller, M. 1984a. Relationship between rank and composition of aromatic hydrocarbons for coals of different origins. Org. Geochem. v. 6, p. 423-430.

Radke, M., Willsch, H., and Welte, D. H. 1984b Class separation of aromatic compounds in rock extracts and fossil fuels by liquid chromatography. Anal. Chem. v. 56, p. 2538-2546.

Radke, M. and Welte, D. H. 1983. The Methylphenanthrene Index (MPI): A maturity parameter based

on aromatic hydrocarbons. In. Bjoroy, M. et al. (eds)., *Advances in Organic Geochemistry 1981*, p. 504-512.

Radke, M., Welte, D. H. and Willsch, H. 1982a. Geochemical study on a well in the Western Canada Basin: relation of the aromatic distribution pattern to maturity of organic matter. *Geochim. Cosmochim. Acta*, v. 46, p. 1-10.

Radke, M., Willsch, H., and Leythaeuser, D. 1982b. Aromatic components of coal: relation of distribution pattern to rank. *Geochim. Cosmochim. Acta*, v. 46, p. 1831-1848.

Rashid, M. A. and McAlary, J. D. 1977. Early maturation of organic matter and genesis of hydrocarbons as a result of heat from a piercement salt dome. *Jour. Geochem. Expl.* v. 8, p. 549-569.

Rowland, S. J., and Alexander, R., and Kagi, R. I. 1984. Analysis of trimethylnaphthalenes in petroleum by capillary gas chromatography. *Jour. Chem.* v. 249, p. 407-412.

Senftle, J. T., Brown, J. H., and Larter, S. R. 1987. Refinement of organic petrographic methods for kerogen characterization. *Int. Jour. Coal. Geol.* v. 7, p. 105-118.

Sofer, Z., Zumberge, J. E., and Lay, V., 1986. Stable carbon isotopes and biomarkers as tools in understanding genetic relationship, maturation, biodegradation, and migration of crude oils in the Northern Peruvian Oriente (Maranon) Basin, *Org. Geochem.* v. 10, p. 377-389.

Sofer, Z. 1984. Stable carbon isotope compositions of crude oils: application to source depositional environments and petroleum alteration. *Bull. Amer. Assoc. Petrol. Geol.* v. 68 (1), p. 31-49.

Stach, E., Mackowsky, M. Th., Teichmuller, M., Taylor, G. H., Chandra, D., and Teichmuller, R. 1982. *Textbook of Coal Petrology*. 3rd Ed. 536 p. Borntraeger, Stuttgart.

Teichmuller, M. 1986. Organic petrology of source rocks, history and state of the art. *Org. Geochem.* v. 10 (1-3), p. 581-599.

Tissot, B. and Welte, D. H. 1984. *Petroleum Formation and Occurrence*. Springer-Verlag, Berlin, 699 p.



Villar, H. J., Puttman, W., and Wol, M. 1988. Organic Geochemistry and petrography of Tertiary coals and carbonaceous shales from Argentina. *Org. Geochem.* v. 13 (4-6), p. 1011-1021.

Wade, J. A. and Maclean, B. C. 1990. Aspects of the geology of the Scotian Basin from recent seismic and well data. In. *Geology of the Continental Margin of Eastern Canada*, M. J. Keen and G. L. Williams (eds). *Geology of Canada* no. 2, p. 190-238.

Wade, J. A. In press. Lithostratigraphy 12: Overpressure; in *East Coast Basin Atlas Series: Scotian Shelf*; Atlantic Geoscience Centre, Geological Survey of Canada.

White, C. M. and Lee, M. L. 1980. Identification and geochemical significance of some aromatic components of coal. *Geochem. Cosmochem. Acta*, v. 44, p. 1825-1832.

Whitehurst, D. D., Buttrill, S. E., Derbyshire, F. J., Farcasiu, M., Odoerfer, G. A. and Rudnick, L. R. 1982. New characterization techniques for coal-derived liquids. *Fuel*, v. 61, p. 994-1005.

## **LIST OF TABLES & FIGURES**

### **Tables**

1. Maceral composition (in volume percent) data of various source rock samples. The table also includes well number, depth, formation name and lithology.
2. Maturation ( $R_o$ , TAI,  $T_{max}$ ) fluorescence/oxidation characteristics (based on organic petrography), Rock-Eval pyrolysis and TOC (wt %), kerogen type and oil/gas potential data. The table also includes well number, depth and formation name.
3. Liquid chromatography data of one condensate and thirteen source rock extracts.
4. List of analyzed samples (light oil/condensates and source rock extracts) with depths and formations for isotope study.
5. Stable carbon isotope data of various light oil/condensate and source rock extracts. Samples are from 1991 analysis and pre-1991.
6. List of analyzed samples (light oil/condensates and source rock extracts) for aromatic GC-MS.
7. List of fragment ion derived from aromatic GC-MS peaks
8. Data from cluster analysis of various oil/condensate and source rock extract samples.

### **Figures**

1. Location map of all the boreholes, which were used for all types of geochemical analysis on source rock and light oil/condensates.
- 2a through 2u. A plot of hydrogen index versus oxygen index and hydrogen index versus  $T_{max}$  showing position of various analyzed samples (from twentyone wells) within the various kerogen maturation paths (after Espitalie et al., 1985).
3. 3a through 3n. Gas chromatograms of the saturate fraction of various source rock extracts. Numbers indicate the corresponding carbon numbers.
4. A plot of  $\delta^{13}C$  (stable isotope of carbon) of saturate and aromatic fractions of:

- a. Light oil, condensate and source rock extracts showing the dividing line of terrestrial and marine source (after Sofer, 1984).
- b. Light oil and condensates from 1991 and pre-1991 analysis.

Figures 5 through 16. Descriptions are enclosed within the figures.

Table 1. Maceral Composition (in volume percent) data of source rock samples including well number, depth, formation name and lithology

Well No.	Formation and Age	Lithology	TOC (wt%)	Maceral composition (in volume %)													
				Auto.	Allo.	Inert.	Exin.	Res.	Lamal.	Telel.	Lipdet.	Amorph.	Amorph.	Amorph.	Amorph.	Bitumen	
				Vit.	Vit.							Lip. 1	Lip. 2	Lip. 3	O.N.		
<hr/>																	
Alma																	
F-67																	
(depth in m)																	
	2720 Naskapi	Gr. Silt. sh	2.25	26.2	47.2	12.5	6.3	0.2	1.0	0.8	2.8			0.2		0.2	2.7
	2895 Mississauga	Sandy Lst	0.17	38.0	32.0	6.0	1.5		1.5	1.0				1.0	13.0		6.0
	5045 Verrill Cany.	Dk Gr. sh	4.69	1.6	15.6	3.2			0.6	6.6	1.0	2.8	60.2	1.6			6.8
Chebucto																	
K-90																	
(depth in m)																	
	4075 Naskapi	Lt. Gr. sh	5.13	18.6	35.8	30.4	3.8		1.2		1.2			2.8	1.6		4.6
	4220 Naskapi	Gr. sh	2.43	18.2	28.0	39.6	2.4		7.6		1.2			2.2	0.2		0.6
	4445 Mississauga	Gr. sh	2.45	15.0	38.2	29.4	3.0		4.8	1.4	1.4			2.6	1.6		2.6
	4595 Mississauga	M-Dg sh	2.04	18.6	34.4	25.0	7.6		2.8	0.4	4.0			2.2	1.4		3.6
	4715 Mississauga	M-Dg sh	1.82	24.0	26.8	29.2	7.2		3.2	2.4	5.0			1.2			1.0
	4975 Mississauga	Bk sh	1.47	9.6	29.0	35.4	8.6		2.6	1.8	3.2			8.6			1.2
	5036.5 Mississauga	Dg-Bk sh	2.03	16.0	28.0	25.4	18.6		1.4	1.2	6.6			1.0	0.4		0.8
	5085 Mississauga	Dg-Bk sh	1.50	7.8	31.2	29.2	14.0		1.8	1.2	1.4			10.4	6.6		2.4
	5150 Mississauga	Dg-Bk sh	1.32	2.0	27.2	35.4	7.6		1.2	0.8	1.0	0.2		23.2			1.4
	5220 Mississauga	Mg-Bk sh	1.91	5.2	38.0	37.0	8.2		1.0	0.6	0.6			5.6	0.6		3.4
Cohasset																	
L-97																	
(depth in m)																	
	2135 Naskapi	Bk sh	2.46	26.8	24.2	27.0	13.2	2.8	3.0	1.4	0.4			0.4	0.8		
	2210 Naskapi	Gr-Br. sh	0.52	13.2	20.0	29.6	32.4	0.8	1.2	0.4				1.4			1.0
	4590 Abenaki	Gr. Lst	0.25	4.0	22.8	36.6	28.0	1.8	2.0	0.2	0.4			0.2	2.0		2.0
	4780 Mohecan	Sandy Lst	0.22	3.2	46.6	20.8	24.8			0.6	0.6				1.0		2.4
Cree E-35																	
(depth in ft)																	
	7850 Naskapi	Gr. shaly sst	1.97	22.2	22.2	14.2	34.4	1.2	0.6	0.6	0.2				3.2		1.2
	7920 Naskapi	Olive sh	3.14	10.2	24.8	21.4	17.8	1.4	1.4	0.6				0.2	20.6	0.6	1.0
	8340 Naskapi	Gr-Br sh	1.71	19.4	21.8	18.8	22.6	0.4	0.6		0.6			0.2	13.4	0.4	1.8
	9510 Mississauga	Gr. Lst	1.09	21.6	26.6	20.6	15.8		0.8	0.8	0.6				12.8		0.4
	10080 Mississauga	Sandy sh	1.14	15.2	21.8	18.0	23.0	2.2		1.2	0.8				17.2		0.6
	10300 Mississauga	Dk olive sh	1.76	17.6	25.6	19.6	10.0	1.6	2.0	0.4	0.4				20.6		2.2
	10960 Mississauga	Olive slt	1.24	15.0	32.4	11.6	14.4	1.6	1.4	0.6	5.0			0.6	15.0		2.4
	11260 Mississauga	Dk olive sh	0.72	16.2	34.0	14.4	13.4	1.2	2.8	1.6	3.6			0.4	10.4		2.0
	11900 Mississauga	Dk olive sh	0.81	14.4	38.8	12.4	5.2	0.4	1.2	0.4				0.4	25.2		1.6
	12480 Mississauga	Dk olive sh	1.02	10.2	39.4	13.6	7.2	0.8	0.8		2.8			0.8	20.8	0.4	3.2
	12980 Mississauga	Dk Gr sh	0.94	11.8	27.6	10.2	5.8	1.0	1.2		0.6			0.8	36.6		4.4
Denascota																	
G-32																	
(depth in ft)																	
	7250 Cree	Md Gr sh	0.64	19.0	24.0	10.8	3.2	2.0	0.4	1.6	2.4			0.8	33.4	0.4	2.0

Well No.	Formation and Age	Lithology	TOC (wt%)	Maceral composition (in volume %)												Bitumen
				Auto.	Allo.	Inert.	Exin.	Res.	Lamal.	Telel.	Lipdet.	Amorph.	Amorph.	Amorph.	Amorph.	
				Vit.	Vit.							Lip.	Lip.	Lip.	O.M.	
												1	2	3		
7350	Naskapi	Md Gr sh	2.25	16.4	20.8	8.0	2.8	0.8	0.4	3.6	0.8		0.8	44.8		0.8
7440	Naskapi	Sandy sh	1.48	20.2	23.0	7.6	3.2		0.4	1.6	2.2		2.4	38.2	0.2	1.0
7650	Naskapi	Gr sandy sh	1.25	9.8	34.0	11.8	10.0	0.6	1.2	0.8	0.8		0.4	29.8	0.4	0.4
9450	Mississauga	Dk sh	1.20	14.8	29.6	21.0	5.6	0.4	1.6	0.8	0.6		1.2	24.0		0.4
10420	Verrill Cany.	Md Gr sh	1.20	14.2	25.0	7.2	5.2	0.8	0.4	0.4	1.2		1.6	43.6		0.4
11240	Verrill Cany.	Gr.Lst	1.05	16.8	22.0	7.0	5.2	2.0	0.8		0.8		0.4	41.2	2.0	1.8
11840	Abenaki	Gr.Lst	1.03	18.8	27.6	9.2	2.0	0.8						40.4		1.2
13020	Abenaki	Gr.Lst	0.49	19.8	11.4	2.8	3.6	1.2			0.6			51.0	8.4	1.2
15320	Abenaki	Dk Lst	0.17	11.4	37.6	18.2	3.0			1.4	0.2			26.6	0.6	0.8
Migrant N-20																
(depth in ft)																
7690	Naskapi	Dk sh Lst	1.22	24.0	26.2	8.8	3.2	2.0	1.4	0.8	0.6			31.6		1.4
7780	Naskapi	Dk Gr sh	0.83	25.6	26.6	12.0	6.8	0.8	0.8	1.0	0.8		2.8	21.6	0.4	0.8
7880	Naskapi	Lt-Dk Gr Sh	0.54	27.2	21.2	14.8	13.2	0.8	2.8		1.0		2.0	16.2		0.8
8670	Mississauga	Dk calc sh	0.80	21.6	38.8	13.8	4.4	1.6	1.0		0.4		1.2	16.8	0.2	0.2
8950	Mississauga	Gr Slt	18.57	20.4	37.6	9.2	6.8	2.4	1.2				0.8	20.4		1.2
9450	Mississauga	Dk Gr Sh	9.50	22.4	36.0	10.0	3.6	0.8	0.8		2.8		1.0	21.4	0.8	0.4
9800	Mississauga	Dk Gr Sh	1.41	16.4	34.4	13.4	7.4	0.4	2.0		4.4		0.4	20.0	0.8	0.4
10830	Mississauga	Dk sandy sh	1.02	40.8	9.2	5.2	3.6	0.4	0.8		1.0		0.4	38.2	0.2	0.2
11770	Mississauga	Dk sandy sh	2.06	24.8	21.0	2.8	4.0	0.8	0.4		1.6		0.8	41.8	1.6	0.4
12280	Mississauga	Dk Gr sh	1.17	24.2	15.8	5.8	1.2	0.4	0.4		2.4		0.8	48.2	1.0	
12760	Mississauga	Dk Gr sh	1.09	13.2	19.2	9.6	2.2	1.8	0.8		0.6		0.8	51.4	0.4	
13560	MicMac	Dk Br sh	1.33	30.0	9.2	4.4	0.4		1.6		2.4		2.4	47.8		1.8
14180	MicMac	Md-Dk Gr sh	3.79	17.8	18.2	13.6					1.2			46.0	0.4	2.8
14660	MicMac	Dk Gr sh	2.96	7.2	12.0	3.2	1.6						41.6	29.2	0.4	4.8
N.Triumph																
B-52																
(depth in m)																
3310	Cree	Dk Gr sh	3.65	25.8	29.8	9.2	3.4	0.6	1.6	1.6	9.0		1.8	11.6	3.8	1.8
3660	Naskapi	Gr sh	3.40	12.4	37.2	13.6	4.0		0.8		1.6		7.4	22.2		0.8
3773.5	Mississauga	Gr sh	1.96	23.2	34.0	15.6	4.8	0.4	1.0	0.4	0.4		5.0	14.0		1.2
N.Triumph																
G-43																
(depth in m)																
3695	Naskapi	Dk Calc sh	4.67	11.6	31.2	8.8	1.6	0.4	0.4		0.4		27.2	17.2	0.4	0.8
4845	Mississauga	Dk Gr sh	4.40	18.2	22.2	3.6	0.4		0.4		0.8		34.4	16.8	0.4	2.8
Olympia A-12																
(depth in m)																
4070	Mississauga	Dk Sandy sh	1.03	28.8	18.4	6.4	4.4	0.4	0.4		0.8		1.6	36.0	2.4	0.4
4340	Mississauga	Br. sh	1.57	16.2	33.2	5.6	1.6		0.4	0.4	2.0		2.0	37.4		1.2
4610	Mississauga	Md Gr sh	1.33	16.6	19.0	10.4	2.0		0.8	0.8	2.0		3.2	43.6		1.6
5430	MicMac	Dk Gr sh	4.54	6.0	20.4	9.6	0.4		0.4	0.4	1.0		32.2	26.8		2.8
5625	MicMac	Gr. Gr sh	6.51	7.6	31.0	7.2	2.8				1.2	1.6	27.2	20.2		1.2
5805	MicMac	Dk Gr sh	6.55	13.0	25.0	10.0				1.0	1.0		15.0	33.0		2.0
6055	MicMac	Dk Gr sh	3.24	11.8	20.6	7.8	4.0		2.4		2.6		22.6	24.0		4.2

Well No.	Formation and Age	Lithology	TOC (wt%)	Maceral composition (in volume %)													
				Auto.	Allo.	Inert.	Exin.	Res.	Lamal.	Telet.	Lipdet.	Amorph.	Amorph.	Amorph.	Amorph.	Bitumen	
				Vit.	Vit.							Lip.	Lip.	Lip.	O.M.		
												1	2	3			
-----																	
Onondaga																	
E-84																	
(depth in ft)																	
	8830 Mississauga	Gr sh	1.68	15.6	27.6	11.2	3.2		1.2		1.2		8.4	30.8		0.8	
	9190 Mississauga	Gr sandy sh	1.47	27.2	23.2	6.8	7.2	1.2	0.8	0.4	0.4		1.2	28.8	1.6	1.2	
	9880 Mississauga	Dk Gr sh	2.18	21.2	27.6	8.2	3.2		0.4	0.8			2.4	34.6	1.2	0.4	
	10780 Mississauga	Gr sh	1.14	23.2	31.0	11.8	3.2	2.0					0.8	28.0			
	11680 Mississauga	Gr sh	1.17	23.4	33.0	13.0	2.8		1.2		0.8		2.0	23.0	0.8		
	12070 Mississauga	Gr Slt sh	1.12	16.8	22.8	21.6	3.6	0.8	0.8		8.4		4.4	20.4		0.4	
	12630 Mississauga	Gr sh	1.28	20.0	24.8	10.0	4.0		1.2		2.0		0.4	37.2		0.4	
	13000 Argo	Slt sh	0.83	11.6	39.4	17.6	7.4				1.2		0.4	21.2	1.2		
	13070 Argo	Slt sh	0.80	14.6	32.4	25.0	6.8	0.4			4.4		0.4	15.8	0.2		
Penobscot																	
L-30																	
(depth in ft)																	
	6950 Cree	Sandy sh	2.20	21.2	21.8	11.4	7.6	0.8		1.6	2.0		1.0	31.4	0.8	0.4	
	7260 Naskapi	Coaly sh	1.63	33.0	23.2	15.8	6.4	0.4	1.6	0.8	1.2		1.2	16.4			
	7360 Naskapi	Dk Sandy sh	2.24	30.8	24.8	10.4	8.8	0.4	0.8		2.0		1.2	19.6	0.4	0.8	
	8650 Mississauga	Dk Sandy sh	1.03	24.8	25.2	17.6	4.8	0.4	0.6	1.2	2.4		1.6	21.2		0.2	
	11239 MicMac	Dk Slt sh	0.07	13.0	33.0	23.0	3.0		1.6				5.4	21.0			
	12420 MicMac	Dk Calc sh	1.13	21.0	37.4	13.6	2.4		0.4		1.2			23.2	0.8		
	12780 MicMac	Bk sh	1.19	18.8	33.8	16.0	4.8	0.8		0.4	2.8		0.4	20.2	2.0		
	13311.2 MicMac	Bk sh	0.44	12.8	33.2	25.8	8.2		2.6	0.4			6.6	10.4			
	13610 MicMac	Md-Dk Gr sh	0.70	14.0	35.6	18.4	6.0	0.8	0.8		3.2	0.6	1.8	16.4	1.2	1.2	
	13990 MicMac	Md-Dk Gr sh	0.71	13.2	38.2	19.4	2.0	0.4	0.8		1.6		1.2	19.6		3.6	
S.Island																	
E-48																	
(depth in ft)																	
	7380 Naskapi	Dk sh	2.39	22.0	22.0	10.4	2.8	0.4	0.4		8.0		0.8	32.4		0.8	
	7960 Naskapi	Dk Gr sh	1.29	29.0	20.4	10.4	6.8		2.0	0.4	2.8		0.4	25.8		2.0	
	8060 Naskapi	Calc. sh	1.95	19.6	17.8	11.4	12.0		1.6		2.0		1.6	32.4	1.0	0.6	
	8260 Naskapi	Gr sh	0.69	26.0	28.4	14.0	8.0	1.2	2.4	1.2	5.0		2.8	10.2	0.4	0.4	
S.Island																	
O-47																	
	6229.5 Cree	Br. sh	1.31	33.8	26.0	15.6	4.8	0.4	0.8	0.4	4.8		0.4	12.6		0.4	
	7820 Cree	Gr Sandy sh	1.35	29.2	23.6	10.4	14.8	0.4	1.6		5.2		2.4	12.0	0.2	0.2	
	8120 Naskapi	Md Fr sh	1.65	27.2	28.6	14.0	9.6		0.8	0.4	4.8		0.4	13.6	0.4	0.2	
	8470 Mississauga	Gr Sandy sh	1.95	23.8	29.8	15.6	6.4	1.6	2.0		4.4		4.4	10.4	1.2	0.4	
	8610 Mississauga	Dk Gr sh	1.34	23.2	30.4	14.8	2.8	0.4	0.8		4.8	0.2	0.4	21.8		0.4	
	11800 Mississauga	Dk Br sh	0.73	26.4	16.4	4.4	2.4	0.4	1.6	0.4	7.2		5.6	34.4		0.8	
S.Desbarres																	
O-76																	
(depth in m)																	
	3801.7 Mississauga	Slt sh	3.56	30.4	10.8	4.4	4.0	4.4	3.2	0.4	4.4	0.4	7.0	29.4		1.2	
	5957.2 MicMac	Dk Slt sh	1.08	32.8	26.6	4.8	3.6		0.4	1.4	6.4	0.4	0.4	21.2	0.4	0.8	
South Sable																	
B-44																	
(depth in m)																	
	3938 Mississauga	Dk Gr sh	2.08	25.6	42.4	5.4	2.4	1.6	0.4		5.0		1.2	15.6		0.4	
	4990 Verrill Cany.	Slt sh	1.06	17.2	31.2	12.0	4.8		0.8	0.4	3.6		6.6	21.0		2.4	

Well No.	Formation and Age	Lithology	TOC (wt%)	Maceral composition (in volume %)											
				Auto. Vit.	Allo. Vit.	Inert.	Exin.	Res.	Lam.	Telel.	Lipdet.	Amorph. Lip.	Amorph. Lip.	Amorph. Lip.	Amorph. O.M.
												1	2	3	
	5045 Verrill Cany.	Slt sh	1.09	10.8	34.0	14.0	1.0		1.2	1.2	3.6		5.2	27.2	0.6
	5160 Verrill Cany.	Dk Gr sh	1.21	14.8	34.8	13.2	2.4		1.2		6.0		4.0	20.4	1.6
	5200 Verrill Cany.	Dk Gr sh	1.10	16.0	29.2	8.0	1.2		0.8		12.4	0.2	2.6	26.8	1.2
Thebaud C-74															
(depth in m)															
	2550 Naskapi	Dk Gr sh	1.56	29.4	24.6	14.2	4.0				1.2		4.2	22.4	
	2620 Naskapi	Dk Gr sh	1.09	25.6	21.4	6.0	8.8	1.6	1.2	1.2	0.8		2.0	30.2	0.8
	3858.6 Mississauga	Dk Gr sh	1.73	25.2	18.6	3.6	5.6				1.6		1.6	43.4	0.2
	3910.6 Mississauga	Gr Clst	1.08	23.8	22.0	6.2	3.2	2.4	1.6	0.8	1.8	0.2	2.8	27.6	7.2
	4095 Mississauga	Dk Gr sh	0.85	14.6	28.6	5.2	2.8	0.4			6.4		4.8	30.4	0.4
	4260 Mississauga	Dk Br sh	2.54	12.0	34.0	19.6	1.4						3.4	25.6	
	4770 Mississauga	Dk Sandy sh	12.49	7.4	14.8	40.6							29.6		3.6
	4945 Mississauga	Dk Sh sst	10.81	8.0	2.0	38.0	12.0						18.0	2.0	8.0
	5075 Mississauga	Slt Dk sh	4.91	3.8		20.8							9.4	3.8	13.2
Uniacke G-72															
	2675 Mississauga	Gr sh	5.64	24.8	37.4	9.2	5.2	2.4	0.6		0.8		1.4	17.0	0.8
	4960 MicMac	Gr Calc sh	0.98	20.0	35.6	14.0	7.0	1.0	0.4	0.6	0.4	1.0	2.4	15.6	0.4
	5220 MicMac	Gr Calc sh	13.10	6.0	28.0	31.0	2.0		1.0				15.0	11.0	
	5240 MicMac	Dk Calc sh	4.21	11.4	38.4	20.0	9.6	0.4	1.2	0.8	0.4		2.2	11.6	
	5715 MicMac	Dk Gr sh	0.85	14.8	39.4	23.6	9.6	1.6	0.4	0.2	0.6		1.2	6.6	0.4
Venture B-52															
	4280 Mississauga	Dk Gr slt	0.85	22.4	37.2	10.8	4.0	1.2	0.8		0.4		2.0	18.8	0.4
	5120.5 Mississauga	Dk Slt sh	2.01	20.2	31.0	10.4	5.6			0.4	3.6		1.2	26.4	0.8
	5335.8 MicMac	Dk Gr sh	1.00	22.4	32.0	16.4	5.0		0.8	1.2	3.8		0.8	16.4	
	5940 MicMac	Md Gr sh	4.28	3.0	4.0	6.0							32.0	7.0	34.0
Venture H-22															
	4965 Mississauga	Gr Sandy sh	3.32	2.8	15.2	47.6	0.6						22.0	7.8	
	5046.5 Mississauga	Dk Gr slt	2.11	18.4	20.4	9.2	4.0	1.2	1.2	0.4	2.4		2.4	38.8	
	5235.1 MicMac	Dk sh	0.91	23.2	24.8	19.6	2.4		0.4	0.4	5.2	0.2	1.4	21.2	
	5410.3 MicMac	Dk Gr slt	0.98	20.6	29.6	17.4	2.4		0.4	1.2	0.4		1.2	26.2	
	5615 MicMac	Dk Gr sh	1.78	3.0	27.0	41.0	2.0						8.0	13.0	3.0
	5870 MicMac	Dk Sandy sh	3.47	4.4	37.0	38.0	0.6			0.6			5.0	14.4	



Well No.	Formation and Age	Lithology	TOC (wt%)	Maceral composition (in volume %)												
				Auto.	Allo.	Inert.	Exin.	Res.	Lam.	Telel.	Lipdet.	Amorph.	Amorph.	Amorph.	Amorph.	Bitumen
				Vit.	Vit.							Lip.	Lip.	Lip.	O.M.	
												1	2	3		
-----																
West Chebucto																
K-20																
(depth in m)																
	3025 Cree	Md Gr sh	2.78	35.8	26.6	8.2	5.6		0.8	0.4	3.2		4.2	12.4		2.8
	3345 Cree	Md Gr sh	3.12	23.4	32.2	7.6	1.6	0.8	3.2	0.8	2.4	0.2	15.6	11.0	0.4	0.8
	3775 Naskapi	Md Gr sh	3.99	17.2	26.4	4.0	1.2	0.8	1.2	0.8	5.6	0.4	21.6	18.8	0.2	1.8
	3950 Naskapi	Md Gr sh	3.66	21.4	29.6	8.8	2.0		0.8	0.8	1.6	1.4	13.0	19.6		1.0
	4205 Mississauga	Md-Dk Gr sh	2.95	18.0	32.2	8.6	0.8		0.8	0.8	4.0	0.4	25.2	8.0		1.2
	4445 Mississauga	Md-Dk Br sh	3.46	10.4	40.6	9.2	2.4		0.2	0.6	2.6		22.6	8.6	1.0	1.8
	4500 Mississauga	Md-Dk Gr sh	2.91	16.2	26.0	13.8	1.2		0.8	0.8	2.0	0.2	22.0	15.2	1.4	0.4
	5210 Mississauga	Blk sh	3.60	11.4	10.6	11.2	0.4		1.2			0.8	48.2	7.0	0.8	8.4
	5366.8 Mississauga	Dk Gr sh	1.96	32.6	25.4	8.6	4.8		1.2	0.4	7.4		7.2	11.6		0.8
Whycocomagh																
N-90																
(depth in m)																
	3310 Mississauga	Md-Dk Gr sh	1.77	31.6	28.2	8.8	2.0		0.4	0.8	1.2		8.4	17.0	0.8	0.8
	3420 Mississauga	Md-Dk Gr sh	1.50	21.2	38.0	14.0	2.8			1.6	1.2		11.2	9.2		0.8

Table 2. Maturation, fluorescence/oxidation characteristic, Rock-Eval pyrolysis and TOC (wt.%), kerogen type and oil and gas potential (based on organic petrography) data of source rock samples including well number, depth, formation name.

Well No.	Formation and Age	Lithology	TOC (wt%)	Ro	TAI	Tmax	HI	OI	PETROGRAPHIC CRITERIA		Kerogen Type (*)	Oil/gas potential (*)
									Fluorescence Character	Oxidation		
<hr/>												
<hr/>												
Alma												
F-67												
(depth in m)												
	2720 Naskapi	Gr. Silt. sh	2.25	0.56	2-	431	58	106	Yellow sp.	Partially oxidized	III	Gas
	2895 Mississauga	Sandy Lst	0.17			424	27	161	Yellow lamal	Partially oxidized	III-IV	Non source
	5045 Verrill Cany.	Dk Gr. sh	4.69			441	578	38	Reg fl.lamal	Partially anoxic	IIA	Oil
Chebucto												
K-90												
(depth in m)												
	4075 Naskapi	Lt. Gr. sh	5.13	0.69	2	433	74	50	Yellow lamal	Partially oxidized	III	Gas
	4220 Naskapi	Gr. sh	2.43	0.75	2	444	48	57	Non fl.	Partially oxidized	III	Gas
	4445 Mississauga	Gr. sh	2.45	0.81	2+	446	57	41	Yellow-Or.	Partially oxidized	III	Gas
	4595 Mississauga	M-Dg sh	2.04	0.80		452	55	44	Non fl.-yellow lamal	Partially oxidized	III	Gas
	4715 Mississauga	M-Dg sh	1.82	0.85		456	52	37	Non fl.	Partially oxidized	III	Gas
	4975 Mississauga	Bk sh	1.47	0.90	2+/3-	458	31	58	Non fl.	Partially oxidized	III	Gas
	5036.5 Mississauga	Dg-Bk sh	2.03	1.10	3	490	67	14	Non fl.	Partially oxidized	IIB-III	Gas-cond.
	5085 Mississauga	Dg-Bk sh	1.50	0.92		451	30	52	Non fl.-yellow bit.	Partially oxidized	III	Gas
	5150 Mississauga	Dg-Bk sh	1.32	0.91		448	26	53	Non fl.-Orange	Partially oxidized	III	Gas
	5220 Mississauga	Mg-Bk sh	1.91	0.99	3+	389	77	62	Non fl.-red fl.	Partially oxidized	III	Gas
Cohasset												
L-97												
(depth in m)												
	2135 Naskapi	Bk sh	2.46	0.37		435	47	46	Yellow fl. exinite	Partially oxidized	III	Gas
	2210 Naskapi	Gr-Br. sh	0.52	0.45		434	30	134	Yellow fl. resinite	Partially oxidized	III	Gas
	4590 Abenaki	Gr. Lst	0.25	0.89		439	16	120	Non fl.	Partially oxidized	III	Gas
	4780 Mohecan	Sandy Lst	0.22	1.08			13	100	Non fl.	Partially oxidized	III-IV	Non source
Cree E-35												
(depth in ft)												
	7850 Naskapi	Gr. shaly sst	1.97	0.42		431	48	32	Yellow fl. exinite	Partially oxidized	III	Gas
	7920 Naskapi	Olive sh	3.14	0.42		431	52	36	Non fl.	Partially oxidized	IIB-III	Cond.-gas
	8340 Naskapi	Gr-Br sh	1.71	0.45		430	37	49	Non fl. spore	Partially oxidized	III	Gas
	9510 Mississauga	Gr. Lst	1.09	0.43		435	33	52	Yellow	Partially oxidized	III	Gas
	10080 Mississauga	Sandy sh	1.14	0.45	1+	434	48	36	Non fl. - few yellow	Partially oxidized	III	Gas
	10300 Mississauga	Dk olive sh	1.76	0.47	2	436	48	36	Yellow solid bitumen	Partially oxidized	III	Gas
	10960 Mississauga	Olive slt	1.24	0.53	2	434	150	86	Yellow solid bitumen	Part.ox.-dysaerobic	IIB-III	Gas-cond.
	11260 Mississauga	Dk olive sh	0.72	0.55		441	38	65	Yellow-orange exinite	Partially oxidized	III	Gas
	11900 Mississauga	Dk olive sh	0.81	0.62	2+	444	40	60	Orange bitumen	Partially oxidized	III	Gas
	12480 Mississauga	Dk olive sh	1.02	0.65		443	55	91	Orange bitumen	Partially oxidized	III	Gas
	12980 Mississauga	Dk Gr sh	0.94	0.70	2+	445	60	126	Orange bitumen	Part.ox.-dysaerobic	IIB	Cond.-gas
Demascota												
G-32												
(depth in ft)												
	7250 Cree	Md Gr sh	0.64	0.39	1+	433	24	83	Yellow solid bitumen	Partially oxidized	III	Gas
	7350 Naskapi	Md Gr sh	2.25		2-	434	43	56	Orange exinite	Part.ox.-dysaerobic	IIB-III	Cond.-gas

Well No.	Formation and Age	Lithology	TOC (wt%)	Ro	TAI	Tmax	HI	OI	PETROGRAPHIC CRITERIA		Kerogen Type (*)	Oil/gas potential (*)
									Fluorescence Character	Oxidation		
7440	Naskapi	Sandy sh	1.48	0.44	2-	434	37	90	--	Part.-totally ox.	III	Gas
7650	Naskapi	Gr sandy sh	1.25		1+2-	429	30	56	Yellow fl. bitumen	Partially oxidized	III	Gas
9450	Mississauga	Dk sh	1.20	0.54	2-	435	55	32	Yellow lamal.	Part.ox.-dysaerobic	IIB-III	Gas-cond.
10420	Verrill Cany.	Md Gr sh	1.20	0.56	2+	442	57	49	Yellow exinite	Part.ox.-dysaerobic	IIB-III	Gas-cond.
11240	Verrill Cany.	Gr.Lst	1.05		2+	441	58	65	Yellow exinite	Part.ox.-dysaerobic	IIB-III	Gas-cond.
11840	Abenaki	Gr.Lst	1.03		2+	445	51	25	Yellow bitumen	Part.ox.-dysaerobic	IIB-III	Gas-cond.
13020	Abenaki	Gr.Lst	0.49	0.57	2+	446	60	216	Orange-red bitumen	Partially oxidized	III	Gas
15320	Abenaki	Dk Lst	0.17	1.21(?)	3-	450	35	294	Non fl.	Partially oxidized	III	Gas
Migrant N-20												
(depth in ft)												
7690	Naskapi	Dk sh Lst	1.22	0.4	1-	430	52	111	Yell-Orange exinite	Partially oxidized	III	Gas
7780	Naskapi	Dk Gr sh	0.83	0.4	1+	433	43	131	Yellow lamal.	Partially oxidized	III	Gas
7880	Naskapi	Lt-Dk Gr Sh	0.54		1-	433	29	83	Yellow exinite	Partially oxidized	III	Gas
8670	Mississauga	Dk calc sh	0.80	0.45	2-	439	31	50	Non fl.	Partially oxidized	III	Gas
8950	Mississauga	Gr Slit	18.57	0.47	1+2-		159	98	Non fl.	Partially oxidized	III	Gas
9450	Mississauga	Dk Gr Sh	9.50		2-		130	84	Orange lamal.	Partially oxidized	III	Gas
9800	Mississauga	Dk Gr Sh	1.41	0.51		438	42	60	Yellow bitumen	Partially oxidized	IIB-III	Gas-cond.
10830	Mississauga	Dk sandy sh	1.02	0.56	2+	441	90	92	Yellow bitumen	Part.ox.-dysaerobic	IIB	Cond.-gas
11770	Mississauga	Dk sandy sh	2.06		2+	448	103	26	Yellow exinite	Part.ox.-dysaerobic	IIB	Cond.-gas
12280	Mississauga	Dk Gr sh	1.17	0.57	2+	447	99	26	Yellow lamal.	Part.ox.-dysaerobic	IIB	Cond.-gas
12760	Mississauga	Dk Gr sh	1.09		2+	447	53	43	Yellow lamal.	Part.ox.-dysaerobic	IIB	Cond.-gas
13560	MicMac	Dk Br sh	1.33	0.7		449	68	18	Yellow bitumen	Part.ox.-dysaerobic	IIB	Cond.-gas
14180	MicMac	Md-Dk Gr sh	3.79		3-	445	47	45	Red bitumen	Part.ox.-dysaerobic	IIB	Cond.-gas
14660	MicMac	Dk Gr sh	2.96	0.79	3-	431	58	63	Yellow bitumen	Dysaerobic	IIA-IIB	Oil-cond.
N.Triumph												
B-52												
(depth in m)												
3310	Cree	Dk Gr sh	3.65	0.55		433	145	38	Yellow lamal.	Dysaerobic	IIB	Cond.-gas
3660	Naskapi	Gr sh	3.40			439	160	49	--	Dysaerobic	IIB	Cond.-gas
3773.5	Mississauga	Gr sh	1.96	0.58		451	93	10	Yellow lamal.	Dysaerobic	IIB	Cond.-gas
N.Triumph												
G-43												
(depth in m)												
3695	Naskapi	Dk Calc sh	4.67	0.46		433	270	23	Yellow bitumen	Dysaerobic	IIA-IIB	Oil-cond.
4845	Mississauga	Dk Gr sh	4.40	0.67		430	274	26	Orange-yellow lamal.	Dysaerobic	IIA-IIB	Oil-cond.
Olympia A-12												
(depth in m)												
4070	Mississauga	Dk Sandy sh	1.03	0.58	2-	444	64	79	Yellow exinite	Partially oxidized	III	Gas
4340	Mississauga	Br. sh	1.57			448	60	37	Yellow bitumen	Partially oxidized	III	Gas
4610	Mississauga	Md Gr sh	1.33	0.62	2+	449	48	57	Non fl.	Part.ox.-dysaerobic	IIB-III	Gas-cond.
5430	MicMac	Dk Gr sh	4.54			432	32	109	Non fl. to brown	Partially anoxic	IIA-IIB	Oil-cond.
5625	MicMac	Gr. Gr sh	6.51	1.08		431	31	57	Non fl.	Partially anoxic	IIA-IIB	Oil-cond.
5805	MicMac	Dk Gr sh	6.55	1.17		434	36	57	Non fl.	Part.ox.-dysaerobic	IIB	Cond.-gas
6055	MicMac	Dk Gr sh	3.24	1.57		436	34	56	Non fl.	Dysaerobic	IIB	Cond.-gas

Well No.	Formation and Age	Lithology	TOC (wt%)	Ro	TAI	Tmax	HI	OI	PETROGRAPHIC CRITERIA		Kerogen Type (*)	Oil/gas potential (*)
									Fluorescence Character	Oxidation		
Onondaga												
E-84												
(depth in ft)												
8830	Mississauga	Gr sh	1.68	0.48	1+	434	46	41	Yellow exinite	Partially oxidized	III	Gas
9190	Mississauga	Gr sandy sh	1.47	0.53	2-	433	50	39	Orange exinite	Partially oxidized	III	Gas
9880	Mississauga	Dk Gr sh	2.18		2+	435	68	37	Red exinite	Partially oxidized	III	Gas
10780	Mississauga	Gr sh	1.14	0.57	2-	434	48	50	Red exinite	Partially oxidized	III	Gas
11680	Mississauga	Gr sh	1.17			445	50	42	Orange exinite	Partially oxidized	III	Gas
12070	Mississauga	Gr Slt sh	1.12	0.65		445	49	38	Orange exinite	Partially oxidized	III	Gas
12630	Mississauga	Gr sh	1.28						Orange liptodet	Partially oxidized	III	Gas
13000	Argo	Slt sh	0.83			450	32	48	Red exinite	Partially oxidized	III	Gas
13070	Argo	Slt sh	0.80	0.7		452	43	85	Red exinite	Partially oxidized	III	Gas
Penobscot												
L-30												
(depth in ft)												
6950	Cree	Sandy sh	2.20		1+	432	104	82	Orange-yellow exinite	Dysaerobic	IIB	Cond.-gas
7260	Naskapi	Coaly sh	1.63	0.38	1+	439	40	46	Yellow lamal.	Partially oxidized	III	Gas
7360	Naskapi	Dk Sandy sh	2.24		1+	437	70	32	Yellow exinite	Partially oxidized	III	Gas
8650	Mississauga	Dk Sandy sh	1.03	0.47	2-	434	43	32	Yellow telalginite	Partially oxidized	III	Gas
11239	MicMac	Dk Slt sh	0.07						Yellow bitumen	Highly oxidized	III-IV	Non source
12420	MicMac	Dk Calc sh	1.13	0.71		448	59	46	Orange exinite	Partially oxidized	III	Gas
12780	MicMac	Bk sh	1.19			448	53	66	Red exinite	Partially oxidized	III	Gas
13311.2	MicMac	Bk sh	0.44	0.67	2-	446	51	77	Non fl.	Partially oxidized	III	Gas
13610	MicMac	Md-Dk Gr sh	0.70			449	55	53	Yellow bitumen	Partially oxidized	III	Gas
13990	MicMac	Md-Dk Gr sh	0.71	0.68	2+	452	45	76	Yellow bitumen	Partially oxidized	III	Gas
S.Island												
E-48												
(depth in ft)												
7380	Naskapi	Dk sh	2.39	0.4	1+	435	68	66	Yellow exinite	Partially oxidized	III	Gas
7960	Naskapi	Dk Gr sh	1.29	0.41	2-	433	40	41	Yellow exinite	Partially oxidized	III	Gas
8060	Naskapi	Calc. sh	1.95	0.45	2-	433	43	51	Orange exinite	Partially oxidized	III	Gas
8260	Naskapi	Gr sh	0.69	0.45	2-	436	37	84	Red telalginite	Partially oxidized	III	Gas
S.Island												
O-47												
6229.5	Cree	Br. sh	1.31	0.33	1-	427	50	34	Non fl.	Partially oxidized	IIB-III	Gas-cond.
7820	Cree	Gr Sandy sh	1.35	0.4	1+	431	48	51	Yellow exinite	Partially oxidized	IIB-III	Gas-cond.
8120	Naskapi	Md Fr sh	1.65	0.39	1+	435	43	58	Yellow exinite	Partially oxidized	IIB-III	Gas-cond.
8470	Mississauga	Gr Sandy sh	1.95		1+	434	43	31	Red exinite	Partially oxidized	III	Gas
8610	Mississauga	Dk Gr sh	1.34	0.44	1+	436	39	30	Yellow lamal.	Partially oxidized	III	Gas
11800	Mississauga	Dk Br sh	0.73	0.64	2+	447	65	119	Yellow bitumen	Dysaerobic	IIB	Cond.-gas
S.Desbarres												
O-76												
(depth in m)												
3801.7	Mississauga	Slt sh	3.56	0.6	2+	438	251	8	Yellow resinite	Anaerobic	IIA-IIB	Oil-cond.
5957.2	MicMac	Dk Slt sh	1.08	1.7	3+	559	22	62		Dysaerobic	IIB	Cond.-gas

Well No.	Formation and Age	Lithology	TOC (wt%)	Ro	TAI	Tmax	HI	OI	PETROGRAPHIC CRITERIA		Kerogen Type (*)	Oil/gas potential (*)
									Fluorescence Character	Oxidation		
South Sable												
B-44												
(depth in m)												
3938	Mississauga	Dk Gr sh	2.08	0.71	2-	448	101	26	Yellow resinite	Dysaerobic	IIB	Cond.-gas
4990	Verrill Cany.	Slt sh	1.06	0.84		455	37	117	Red bitumen	Partially oxidized	III	Gas
5045	Verrill Cany.	Slt sh	1.09	0.89		461	35	154	Non fl.	Partially oxidized	III	Gas
5160	Verrill Cany.	Dk Gr sh	1.21	0.97	2+/3-	461	33	202	Red lamal.	Partially oxidized	III	Gas
5200	Verrill Cany.	Dk Gr sh	1.10	1.09		472	39	190	Non fl.	Part.ox.-dysaerobic	IIB-III	Gas-cond.
Thebaud C-74												
(depth in m)												
2550	Naskapi	Dk Gr sh	1.56	0.42	1-/1+	433	52	56	Yellow exinite	Partially oxidized	III	Gas
2620	Naskapi	Dk Gr sh	1.09	0.44		433	45	76	Yellow exinite	Partially oxidized	III	Gas
3858.6	Mississauga	Dk Gr sh	1.73	0.62	2+	448	84	47	Yellow exinite	Dysaerobic	IIB-III	Gas-cond.
3910.6	Mississauga	Gr Clst	1.08	0.6		442	94	14	Orange exinite	Dysaerobic	IIB	Cond.-gas
4095	Mississauga	Dk Gr sh	0.85	0.64	2+/3-	449	58	118	Yellow bitumen	Part.ox.-dysaerobic	IIB-III	Gas-cond.
4260	Mississauga	Dk Br sh	2.54	0.67		436	55	170	Non fl.	Partially oxidized	III	Gas
4770	Mississauga	Dk Sandy sh	12.49	0.71		425	111	109	Non fl.	Partially oxidized	III	Gas
4945	Mississauga	Dk Sh sst	10.81	0.81		425	95	119	Non fl.	Partially oxidized	III	Gas
5075	Mississauga	Slt Dk sh	4.91	0.91		432	60	144	Non fl.	Partially oxidized	III	Gas
Uniacke												
G-72												
2675	Mississauga	Gr sh	5.64	0.41	2-	436	65	62	Yellow exinite	Partially oxidized	III	Gas
4960	MicMac	Gr Calc sh	0.98	0.81	2+	437	19	128	Non fl.	Partially oxidized	III	Gas
5220	MicMac	Gr Calc sh	13.10		3-	430	56	122	Non fl.	Partially oxidized	III	Gas
5240	MicMac	Dk Calc sh	4.21	1.03	3-		79	122	Orange bitumen	Partially oxidized	III	Gas
5715	MicMac	Dk Gr sh	0.85	1.26	3+	440	37	123	Red bitumen	Partially oxidized	III	Gas
Venture												
B-52												
4280	Mississauga	Dk Gr slt	0.85	0.67	2	446	61	83	Non fl.	Partially oxidized	III	Gas
5120.5	Mississauga	Dk Slt sh	2.01	1.06	2+	473	69	10	Yellow bitumen	Partially oxidized	III	Gas
5335.8	MicMac	Dk Gr sh	1.00	1.44	3-	509	26	246	Non fl.	Partially oxidized	III	Gas
5940	MicMac	Md Gr sh	4.28	1.40(?)		432	34	77	Non fl.	Partially oxidized	III	Gas
Venture												
H-22												
4965	Mississauga	Gr Sandy sh	3.32	0.81		436	24	100	Non fl.	Partially oxidized	III	Gas
5046.5	Mississauga	Dk Gr slt	2.11	0.99	2+/3	465	54	6	Non fl.	Dysaerobic-part.ox.	IIB	Cond.-gas
5235.1	MicMac	Dk sh	0.91	1.17	3-	471	35	20	Yellow bitumen	Partially oxidized	III	Gas
5410.3	MicMac	Dk Gr slt	0.98	1.4	3-	489	35	15	Non fl.	Partially oxidized	III	Gas
5615	MicMac	Dk Gr sh	1.78			414	25	127	Non fl.; 1 red fl res	Oxidized	III-IV	Non source
5870	MicMac	Dk Sandy sh	3.47	1.64	3	426	26	86	Non fl.	Partially oxidized	III	Gas

Well No.	Formation and Age	Lithology	TOC (wt%)	Ro	TAI	Tmax	HI	OI	PETROGRAPHIC CRITERIA		Kerogen Type (*)	Oil/gas potential (*)
									Fluorescence Character	Oxidation		
West Chebucto												
K-20												
(depth in m)												
3025	Cree	Md Gr sh	2.78	0.48		433	195	43	Orange exinite	Dysaerobic	IIB	Cond.-gas
3345	Cree	Md Gr sh	3.12	0.51	1+	435	276	48	Orange exinite	Dysaerobic	IIB	Cond.-gas
3775	Naskapi	Md Gr sh	3.99	0.6		435	250	31	Red telalginite	Dysaerobic	IIB	Cond.-gas
3950	Naskapi	Md Gr sh	3.66	0.67		438	251	37	Yellow-red telalg	Dysaerobic	IIB	Cond.-gas
4205	Mississauga	Md-Dk Gr sh	2.95	0.67		437	214	56	Non fl.	Dysaerobic	IIB	Cond.-gas
4445	Mississauga	Md-Dk Br sh	3.46	0.78		433	167	49	Red lamal.	Dysaerobic	IIB	Cond.-gas
4500	Mississauga	Md-Dk Gr sh	2.91	0.84		438	195	53	Red lamal.	Dysaerobic	IIB	Cond.-gas
5210	Mississauga	Blk sh	3.60	1.19		435	299	63	Yellow oil droplet	Dysaerobic	IIA-IIB	Oil-cond.
5366.8	Mississauga	Dk Gr sh	1.96	1.4		519	27	113	Red fl. exinite	Partially oxidized	III	Gas
Whycocomagh												
N-90												
(depth in m)												
3310	Mississauga	Md-Dk Gr sh	1.77	0.56	2-	423	190	115	Non fl.	Dysaerobic	IIB	Cond.-gas
3420	Mississauga	Md-Dk Gr sh	1.50	0.6	2-	408	146	89	Non fl.	Partially oxidized	IIB	Cond.-gas

\*Kerogen Type based on petrographic criteria

Sh = shale Lst = Limestone Sst = Sandstone; Dk Gr = Dark Gray; M-dg = Medium to Dark Gray  
Lt. Gr. = Light Gray; Bk = Black; Gr-Br = Gray to Brown;

Table 3 : Weight chemistry data of condensate and source rock extracts

Well No.	Depth	Saturate (% of Extr.)	Aromatics (% of Extr.)	NSO & Asph. (% of Extr.)
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Condensates

Bluenose 2G-47	4577m	55.5	44.6	1.9
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Source rock extracts

Alma F-67	5045m	10.1	0.9	87.6
Cree E-35	3340m	8.2	7.5	82.4
Migrant N-20	11770 ft	9.5	7.3	81.6
N. Triumph G-43	3695m	41.2	3.2	51.4
N. Triumph G-43	4845m	38.6	1.6	38.4
Penobscot L-30	6950 ft	22.5	10.9	60.4
S. Desbarres O-76	3801m	4.8	10.5	80.1
South Sable B-44	3938m	6.8	6.1	81.6
Thebaud C-74	3911m	5.2	9.8	82.1
Venture B-52	5121m	10.1	7.5	77.1
W. Chebucto K-20	3345m	29.5	6.4	62.5
W. Chebucto K-20	5210m	20.7	4.2	68.7
Whycocomagh N-90	3360m	22.5	3.3	68.9

For other data see 1990 report



Table 4: List of analyzed samples, depths and formations for isotope study

No.Well No	Depth	Formation	Analysis year
Crude oil/condensate			
1 Arcadia J-16, DST #5	5156 - 5175m	Abenaki	1991
2 Bluenose 2G-47, DST#8	4576.8-4590m	NicMac	1991
3 Penobscot L-30,Rft #5	8669ft	Mississauga	1991
4 Venture H-22, Dst #5	5021-5025m	NicMac	1991
5 Alma F-67, Dst #7	2872-2890m	Mississauga	Pre-1991
6 Alma F-67, DST#2	3026-3032m	Mississauga	Pre-1991
7 Arcadia J-16, DST #9	4857-4864m	Abenaki	Pre-1991
8 Banquereau C-21,DST#2	3585-3596m	Mississauga	Pre-1991
9 Chebucto K-20, DST #4	4227-4238m	Mississauga	Pre-1991
10 Citnalta I-59, DST#3	3777-3781m	Mississauga	Pre-1991
11 Cohasset A-52, DST #5	2149-2153m	Logan Canyon	Pre-1991
12 Cohasset A-52, DST #2	2337-2341m	Logan Canyon	Pre-1991
13 Cohasset D-42, DST #7	1961-1865m	Logan Canyon	Pre-1991
14 Cohasset D-42, DST #3	2248-2255m	Logan Canyon	Pre-1991
15 Glenelg J-48, DST #9	3062-3065m	Logan Canyon	Pre-1991
16 Glenelg J-48, DST #8	3491-3495	Mississauga	Pre-1991
17 N.Trumph B-52,DST#4	3771-3777m	Mississauga	Pre-1991
18 N.Trumph G-43,DST#1	3835-3846m	Mississauga	Pre-1991
19 Olympia A-12, DST #8	4525-4538m	Mississauga	Pre-1991
20 Olympia A-12, DST#5	4664-4678m	Nic Mac	Pre-1991
21 Panuke B-90, DST #1	2293-2299m	Mississauga	Pre-1991
22 Primrose A-41,DST#2	1511-1530m	Wyandot	Pre-1991
23 Primrose N-90,DST #1	1551-1560m	Dawson Canyon	Pre-1991
24 S.Island E-48, DST#6	2002-2003m	Logan Canyon	Pre-1991
25 S. Island E-48, DST#5	2173-2176m	Logan Canyon	Pre-1991
26 S.Island 3H-58, DST#4	1632-1633m	Logan Canyon	Pre-1991
27 S.Venture O-59,DST#10	4255-4267m	Mississauga	Pre-1991
28 S. Venture O-59,DST#5	5035-5050m	Mississauga	Pre-1991
29 Thebaud C-74, DST#9	3865-3888m	Mississauga	Pre-1991
30 Thebaud C-74, DST#4	4508-4521m	Mississauga	Pre-1991
31 Venture B-13, DST#1	4475-4485m	Mississauga	Pre-1991
32 Venture B-43, DST#2	5478-5498m	Nic Mac	Pre-1991
33 Venture B-52, DST#13	4920-4925m	Mississauga	Pre-1991

Table 4: List of analyzed samples, depths and formations for isotope study

No. Well No	Depth	Formation	Analysis year
Source-Rock Extracts			
1 Alma F-67	5045m	Verrill Canyon	1991
2 Cree-35	10960 ft	Mississauga	1991
3 Migrant N-20	11770 ft	Mississauga	1991
4 N. Triumph G-43	3695m	Logan Canyon	1991
5 N. Triumph G-43	4845m	Mississauga	1991
6 Penobscot L-30	6950 ft	Logan Canyon	1991
7 S. Desbarres O-76	3801m	Mississauga	1991
8 South Sable B-44	3938m	Mississauga	1991
9 Thebaud C-74	3911m	Mississauga	1991
10 Venture B-52	5121m	Mississauga	1991
11 West Chebucto K-20	3345m	Logan Canyon	1991
12 West Chebucto K-20	5210m	Mississauga	1991
13 Whycocomagh N-90	3310m	Mississauga	1991
14 Alma F-67	4500m	Verrill Canyon	Pre-1991
15 Cohasset A-52	2275m	Logan Canyon	Pre-1991
16 Cohasset A-52	2278m	Logan Canyon	Pre-1991
17 Cohasset D-42	4410m	Abenaki	Pre-1991
18 Cohasset D-42	4425m	Abenaki	Pre-1991
19 Evangeline H-98	5020m	Shortland Sh (Logan Canyon)	Pre-1991
20 Glenelg J-48	5186m	Verrill Canyon	Pre-1991
21 Sable Island E-48	2490m	Logan Canyon	Pre-1991
22 Sable Island O-47	3849m	Mississauga	Pre-1991
23 South Venture O-59	6105m	Mic Mac	Pre-1991

Table 5: Stable carbon isotope data of oil/condensate and  
source rock extracts

Samples		del 13C sat	del 13C arom
CRUDE OIL/CONDENSATE	DST/RFT		
1 Arcadia J-16	#5	-26.5	-24.3 *
2 Bluenose 2G-47	#8	-27.4	-25.8 *
3 Penobscot L-30	#5	-27.1	-25.8 *
4 Venture H-22	#5	-26.9	-25.3 *
5 Alma F-67	#7	-26.9	-25.2 +
6 Alma F-67	#2	-27.4	-25.9 +
7 Arcadia J-16	#9	-26.6	-24.8 +
8 Banquereau C-21	#2	-26.9	-25.2 +
9 Chebucto K-90	#4	-26.1	-24.4 +
10 Citnaita I-59	#3	-26.7	-25.9 +
11 Cohasset A-52	#5	-28.4	-27.7 +
12 Cohasset A-52	#2	-27.1	-25.4 +
13 Cohasset D-52	#7	-27.0	-25.7 +
14 Cohasset D-52	#3	-27.0	-25.4 +
15 Glenelg J-48	#9	-25.9	-24.2 +
16 Glenelg J-48	#8	-26.2	-24.4 +
17 N.Triumph B-52	#4	-26.7	-24.8 +
18 N.Triumph G-43	#1	-27.4	-25.3 +
19 Olympia A-12	#8	-26.8	-25.9 +
20 Olympia A-12	#5	-27.1	-25.6 +
21 Panuke B-90	#1	-27.2	-25.3 +
22 Primrose A-41	#2	-26.9	-26.4 +
23 Primrose N-90	#1	-26.1	-24.7 +
24 Sable Is. E-48	#6	-26.2	-25.5 +
25 Sable Is. E-48	#5	-26.7	-25.3 +
26 Sable Is. 3H-58	#4	-26.2	-25.5 +
27 S. Venture O-59	#10	-27.3	-25.6 +
28 S. Venture O-59	#5	-26.5	-24.4 +
29 Thebaud C-74	#9	-26.9	-25.4 +
30 Thebaud C-74	#4	-26.6	-24.7 +
33 Venture B-52	#13	-26.3	-25.3 +
31 Venture B-13	#11	-27.1	-25.9 +
32 Venture B-43	#2	-26.4	-24.5 +

Table 5 : Stable carbon isotope data of oil/condensate and  
source rock extracts

Samples		del 13C sat	del 13C arom
-----		-----	-----
SOURCE ROCK EXTRACTS			
1 Alma F-67	5045m	-28.3	-23.7 *
2 Cree E-35	10960'	-27.9	-26.5 *
3 Migrant N-20	11770'	-27.7	-26.1 *
4 N.Triumph G-43	3695m	-28.6	-25.3 *
5 N.Triumph G-43	4845m	-28.9	-24.9 *
6 Penobscot L-30	6950'	-27.8	-26.6 *
7 S. Desbarres O-76	3801m	-28.4	-26.1 *
8 South Sable B-44	3938m	-28.9	-26.2 *
9 Thebaud C-74	3911m	-28.7	-26.0 *
10 Venture B-52	5121m	-27.2	-25.4 *
11 W.Chebucto K-20	3345m	-28.6	-25.7 *
12 W.Chebucto K-20	5210m	-28.5	-26.8 *
13 Whycocomagh N-90	3360m	-28.0	-26.3 *
14 Alma F-67	4500m	-28.5	-24.0 +
15 Cohasset A-52	2275m	-26.8	-25.3 +
16 Cohasset A-52	2275.75m	-29.2	-27.5 +
17 Cohasset D-42	4410m	-27.2	-25.8 +
18 Cohasset D-42	4425m	-26.7	-25.0 +
19 Evangeline H-98	5020m	-27.9	-26.4 +
20 Glenelg J-48	5186m	-28.3	-27.1 +
21 Sable Is. E-48	2490m	-26.9	-25.7 +
22 Sable Is. O-47	3849m	-26.9	-26.0 +
23 S.Venture O-59	6105m	-27.5	-26.7 +

\* = Analyzed in 1991; + = Data from pre-1991 reports

Table 6 : List of analysed samples, their depths, and formation names for aromatic GC-MS study

No. Well No.	Depth	Formation	Analysis Year	I.D. No.
Crude oil/condensate				
1 Arcadia J-16, DST#5	5156-5175m	Abenaki	1991	NS9116
2 Banquereau C-21, DST#2	3585-3596m	Mississauga	1991	NS9113
3 Bluenose 2G-47, DST#8	4576-4590m	Mic Mac	1991	NS9115
4 Citnalta I-59, DST#3	3777-3781m	Mississauga	1991	NS9112
5 Penobscot L-30, RFT#5	8669 ft	Mississauga	1991	NS9114
6 Thebaud C-74, DST#9	3865-3888m	Mississauga	1991	NS9118
7 Venture H-22, DST#5	5021-5025m	Mic Mac	1991	NS9117
8 Chebucto K-90, DST#4	4227-4238m	Mississauga	Pre-1991	NS9001
9 Cohasset A-52, DST#5	2149-2153m	Logan Canyon	Pre-1991	NS9004
10 Cohasset D-42, DST#7	1961-1965m	Logan Canyon	Pre-1991	NS9002
11 Glenelg J-48, DST#8	3491-3495m	Mississauga	Pre-1991	NS9010
12 N. Triumph B-52, DST#4	3771-3777m	Mississauga	Pre-1991	NS9006
13 Olympia A-12, DST#5	4664-4678m	Mic Mac	Pre-1991	NS9007
14 Panuke B-90, DST#1	2293-2299m	Mississauga	Pre-1991	NS9003
15 S. Island 3H-58, DST#4	1632-1635m	Logan Canyon	Pre-1991	NS9005
16 S. Venture O-59, DST#10	4255-4267m	Mississauga	Pre-1991	NS9009
17 S. Venture O-59, DST#5	5035-5050m	Mississauga	Pre-1991	NS9008
Source-Rock Extracts				
1 Alma F-67	5045m	Verrill Canyon	1991	NS9108
2 Migrant N-20	11770 ft	Mississauga	1991	NS9101
3 N. Triumph G-43	3695m	Logan Canyon	1991	NS9109
4 N. Triumph G-43	4845m	Mississauga	1991	NS9103
5 Penobscot L-30	6950 ft	Logan Canyon	1991	NS9105
6 S. Desbarres O-76	3861m	Mississauga	1991	NS9107
7 South Sable B-44	3938m	Mississauga	1991	NS9111
8 Thebaud C-74	3911m	Mississauga	1991	NS9110
9 Venture B-52	5121m	Mississauga	1991	NS9102
10 W. Chebucto K-20	5210m	Mississauga	1991	NS9104
11 Whycomomagh N-30	3360m	Mississauga	1991	NS9106
12 Alma F-67	4500m	Verrill Canyon	Pre-1991	NS9013
13 Cohasset A-52	2275m	Logan Canyon	Pre-1991	NS9012
14 Cohasset D-42	4410m	Abenaki	Pre-1991	NS9011
15 S. Venture O-59	6105m	Mic Mac	Pre-1991	NS9014

Table 7 — GCMS peaks. See text for explanation of parameters.

<i>Peaks</i>	<i>Avg Ret Time</i> (min.)	<i>Std Dev Area</i> (log10, norm)	$\Delta a$ (MPI diff.)	<i>Use</i>
<b>m/z 156 (C2-alkylnaphthalenes)</b>				
156a	21.64	0.83	0.21	+
156b	22.22	0.07	0.13	
156c	22.93	0.04	-0.08	
156d	23.07	0.17	-0.23	-
156e	23.79	0.12	-0.24	-
156f	24.38	0.22	-0.45	-
<b>m/z 170 (C3-alkylnaphthalenes)</b>				
170a	26.91	0.15	0.02	*
170b	27.58	0.15	-0.04	*
170c	27.86	0.14	0.21	
170d	28.09	0.09	0.11	
170e	28.72	0.09	-0.06	
170f	28.89	0.10	0.19	
170g	29.46	0.07	-0.14	
170h	30.33	0.33	-0.85	-
<b>m/z 184 (C4-alkylnaphthalenes and dibenzothiophene)</b>				
184a	33.09	0.16	-0.06	*
184b	33.96	0.16	-0.02	*
184c	34.55	0.27	-0.47	-
184d	34.71	0.34	-0.67	-
184e	34.99	0.21	0.04	*
184f	35.32	0.25	-0.44	-
184g	35.46	0.34	-0.39	-
184h	35.67	0.37	-0.43	-
184i	36.26	0.80	-1.44	-
DBT	36.41	1.30	0.35	+
<b>m/z 198 (Methyldibenzothiophenes)</b>				
198a	40.26	0.12	0.13	
198b	40.96	0.12	-0.05	
198c	41.69	1.47	-1.32	-
<b>m/z 212 (Dimethyldibenzothiophenes)</b>				
212a	43.55	0.16	-0.09	*
212b	43.89	0.18	0.15	*
212c	44.43	0.14	0.20	
212d	44.59	0.17	0.12	*
212e	45.19	0.16	-0.16	*
212f	45.35	0.25	-0.15	*
212g	45.80	0.18	-0.02	*

Table 7 — continued				
<i>Peaks</i>	<i>Avg Ret Time</i>	<i>Std Dev Area</i>	$\Delta a$	<i>Use</i>
	(min.)	(log10, norm)	(MPI diff.)	
<b>m/z 182</b>	<b>(Dimethylbiphenyls and methyldibenzofurans)</b>			
182a	29.85	0.81	0.34	+
182b	30.36	0.10	0.15	
182c	30.51	0.02	0.00	
182d	30.93	0.09	0.07	
182e	31.21	0.60	0.67	+
182f	31.98	0.16	-0.02	*
mDBFa	31.65	0.06	0.06	
mDBFb	32.20	0.07	-0.08	
mDBFc	32.52	0.17	0.31	+
<b>m/z 178</b>	<b>(Phenanthrene)</b>			
PHN	37.51	0.06	0.00	
<b>m/z 192</b>	<b>(Methylphenanthrenes)</b>			
192a	41.79	0.12	0.33	+
192b	41.96	0.11	0.27	+
192c	42.59	0.09	0.03	
192d	42.75	0.07	-0.04	
<b>m/z 206</b>	<b>(Dimethylphenanthrenes)</b>			
206a	45.04	0.21	0.03	*
206b	45.57	0.20	-0.19	*
206c	45.69	0.57	0.87	+
206d	45.95	0.22	0.53	+
206e	46.04	0.22	0.50	+
206f	46.57	0.18	0.29	+
206g	46.75	0.16	0.28	+
206h	46.89	0.15	0.07	*
206i	47.14	0.16	0.36	+
206j	47.24	0.17	-0.10	*
206k	47.63	0.15	-0.01	*
206l	48.11	0.66	-1.26	-
<b>m/z 202</b>	<b>(Fluoranthene and pyrene)</b>			
FLAN	47.14	0.19	-0.29	-
PYR	48.68	0.24	-0.20	*
<b>m/z 216</b>	<b>(Methylfluoranthenes and methylpyrenes)</b>			
216a	51.09	0.13	-0.23	-
216b	51.81	0.15	-0.04	*
216c	52.37	1.16	-0.36	-
216d	52.56	0.21	0.14	*
216e	53.24	0.17	-0.14	*
216f	53.45	0.18	-0.17	*

Table 7— continued				
<i>Peaks</i>	<i>Avg Ret Time</i>	<i>Std Dev Area</i>	$\Delta a$	<i>Use</i>
	(min.)	(log10, norm)	(MPI diff.)	
<b>m/z 230</b>	<b>(Dimethylfluoranthenes and dimethylpyrenes)</b>			
230a	54.84	0.75	-0.36	-
230b	55.45	0.30	0.24	+
230c	55.62	0.21	0.26	+
230d	56.18	0.19	0.12	*
230e	56.54	0.91	-0.07	
230f	56.71	0.57	0.06	
230g	56.92	0.17	-0.11	*
230h	57.54	0.19	-0.16	*
230i	57.75	0.35	-0.44	-
<b>m/z 228</b>	<b>(Benzo[a]anthracene and chrysene)</b>			
BAN	58.52	0.32	-0.71	-
CHR	58.75	0.03	-0.04	
<b>m/z 242</b>	<b>(Methylchrysene isomers)</b>			
242a	62.08	0.14	0.22	+
242b	62.26	0.19	0.11	*
242c	62.61	0.18	-0.25	-
242d	62.95	0.20	-0.04	*
<b>m/z 252</b>	<b>(Benzo[a]pyrene and isomers)</b>			
252a	66.66	0.23	0.12	*
252b	68.34	0.15	0.05	*
252c	68.64	1.47	-1.70	-
252d	69.14	1.73	-2.83	-
<b>m/z 231</b>	<b>(Triaromatic steroids)</b>			
231a	70.71	1.53	-2.62	-
231b	72.37	1.71	-2.23	-
231c	73.74	1.73	-2.42	-
231d	74.41	1.58	-2.19	-
231e	76.09	1.69	-2.50	-





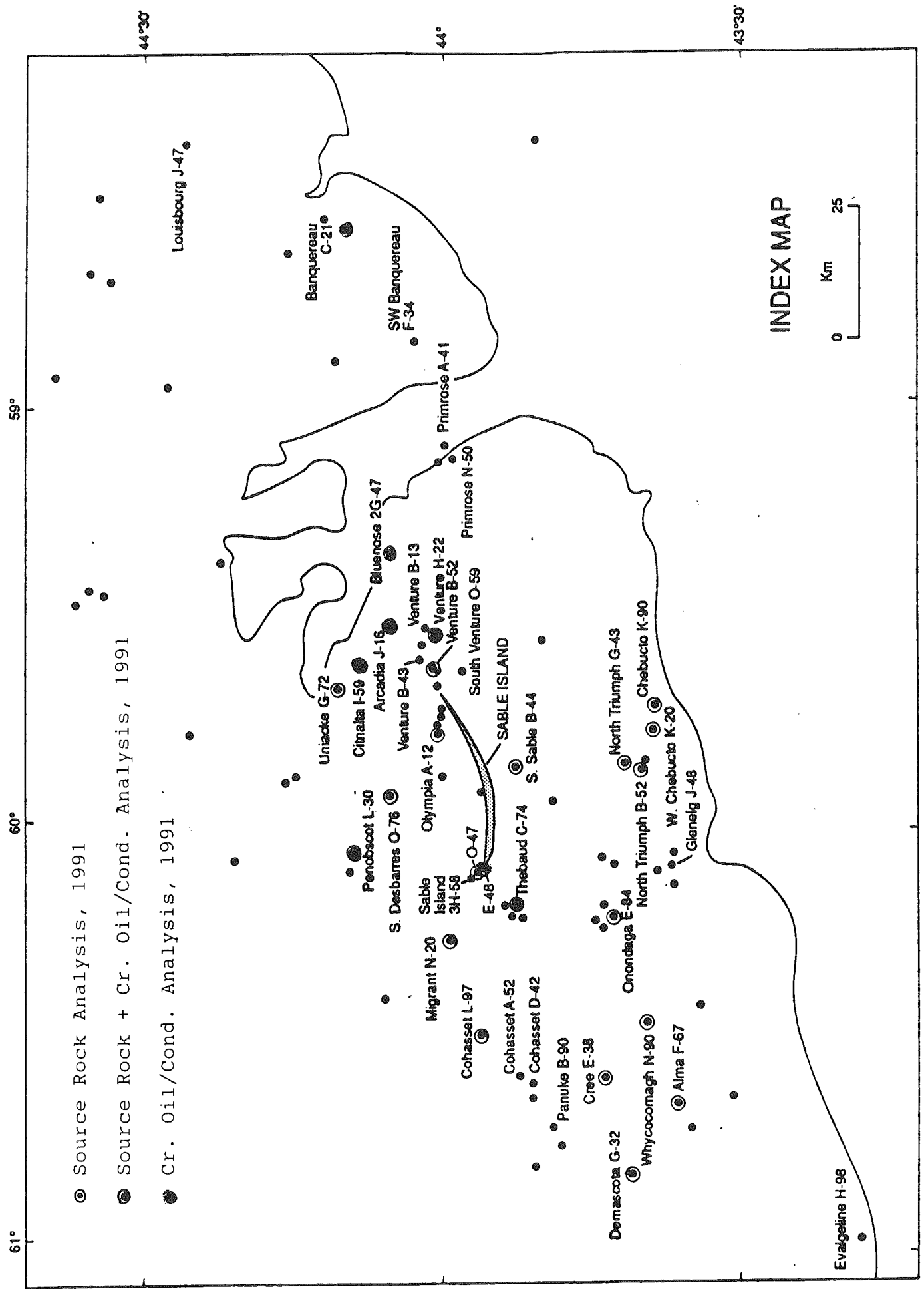


Figure 1

ALMA F-67

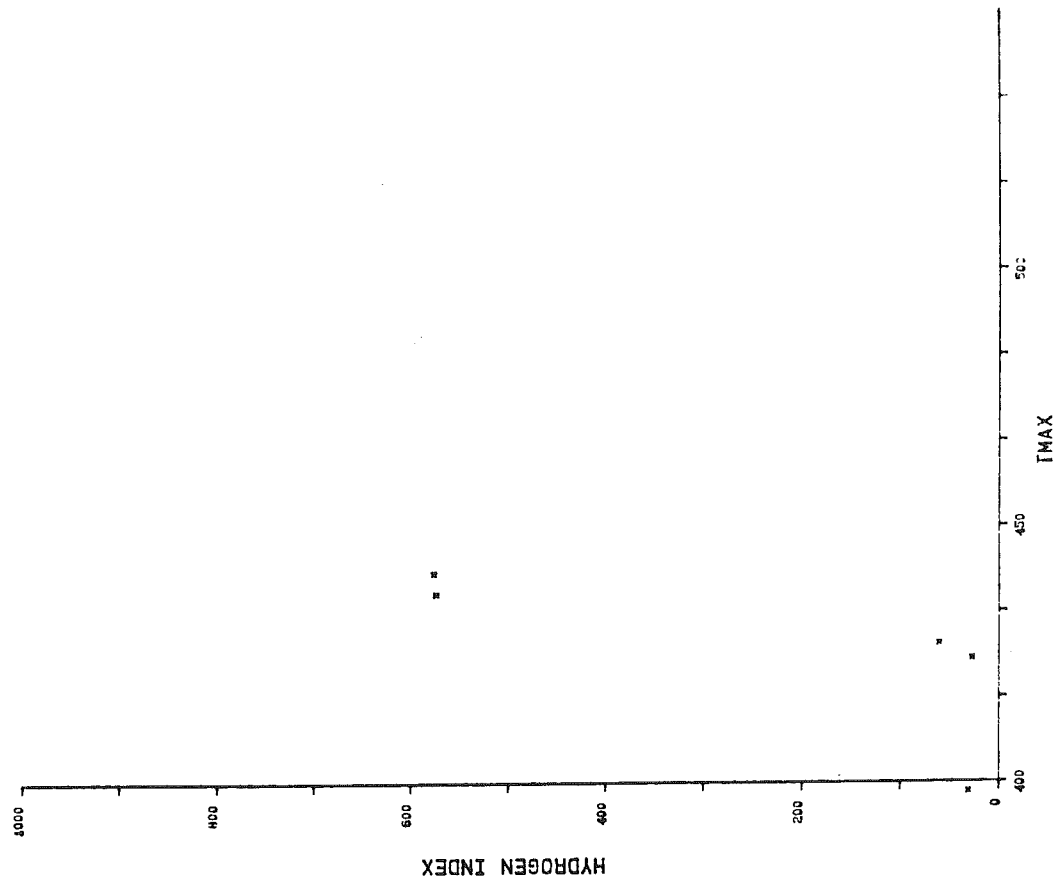
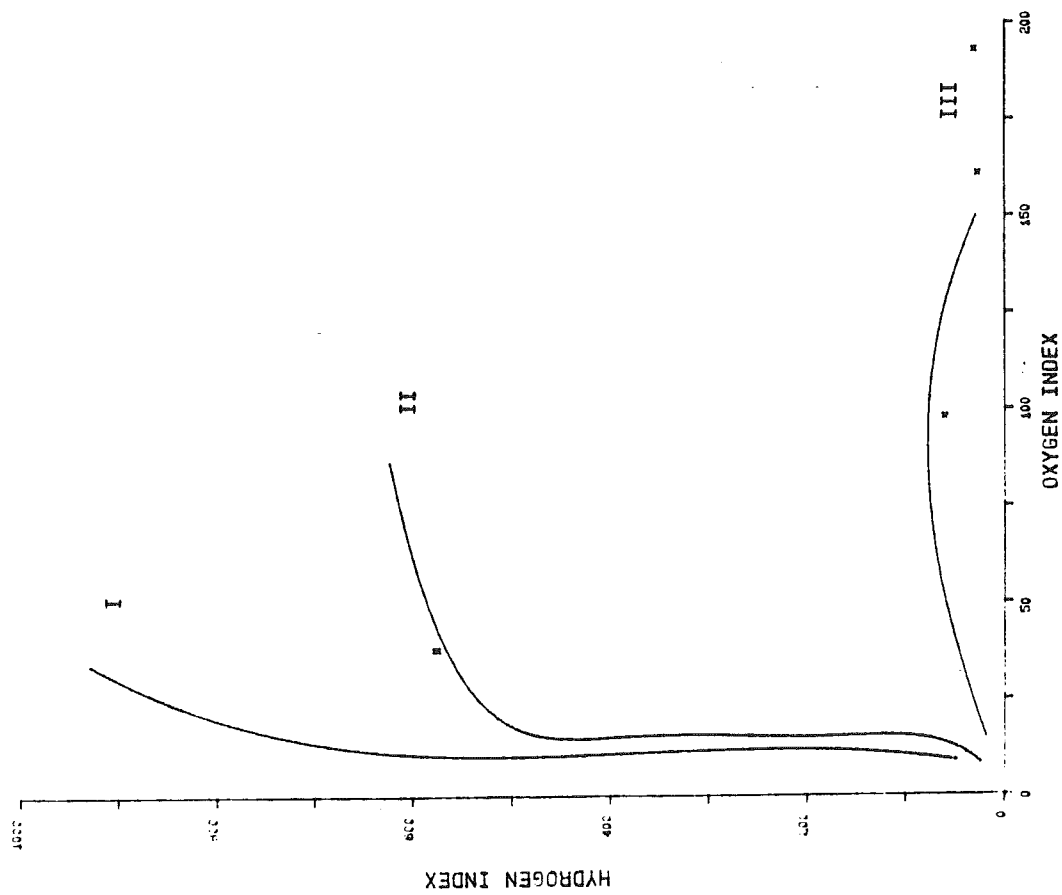


Figure 2a

# CHEBUCTO K-90

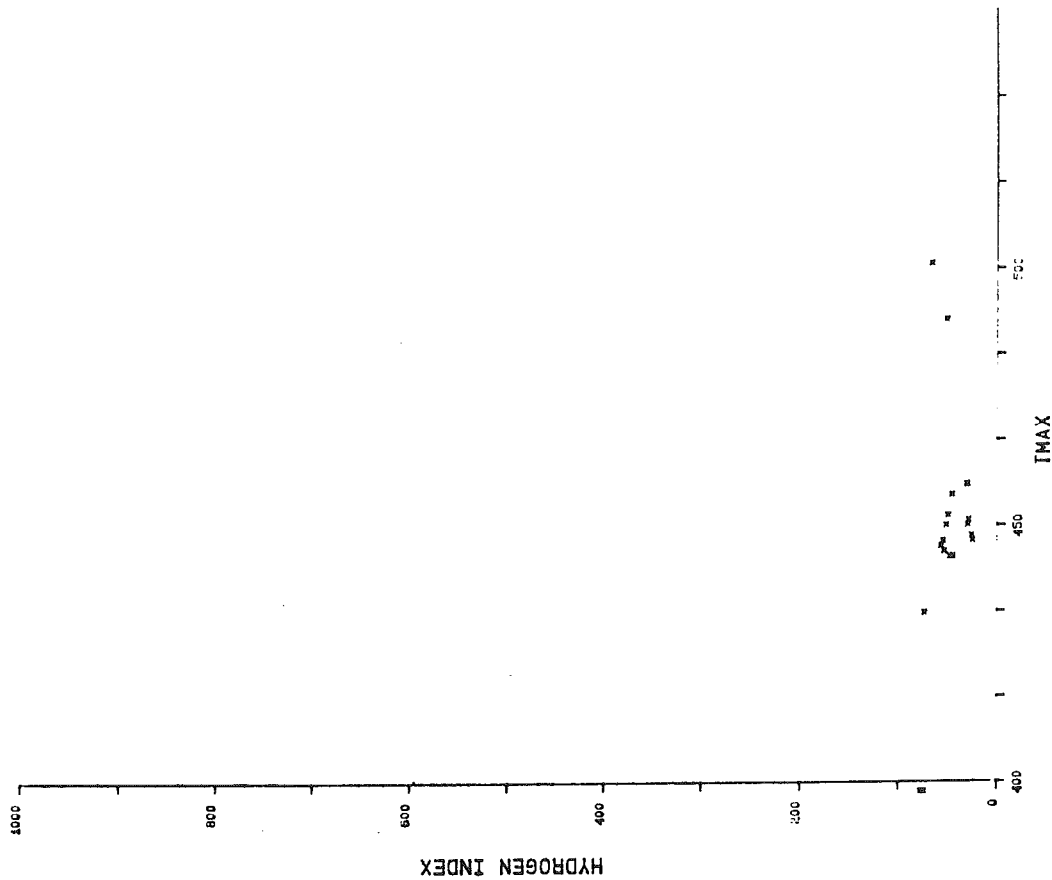
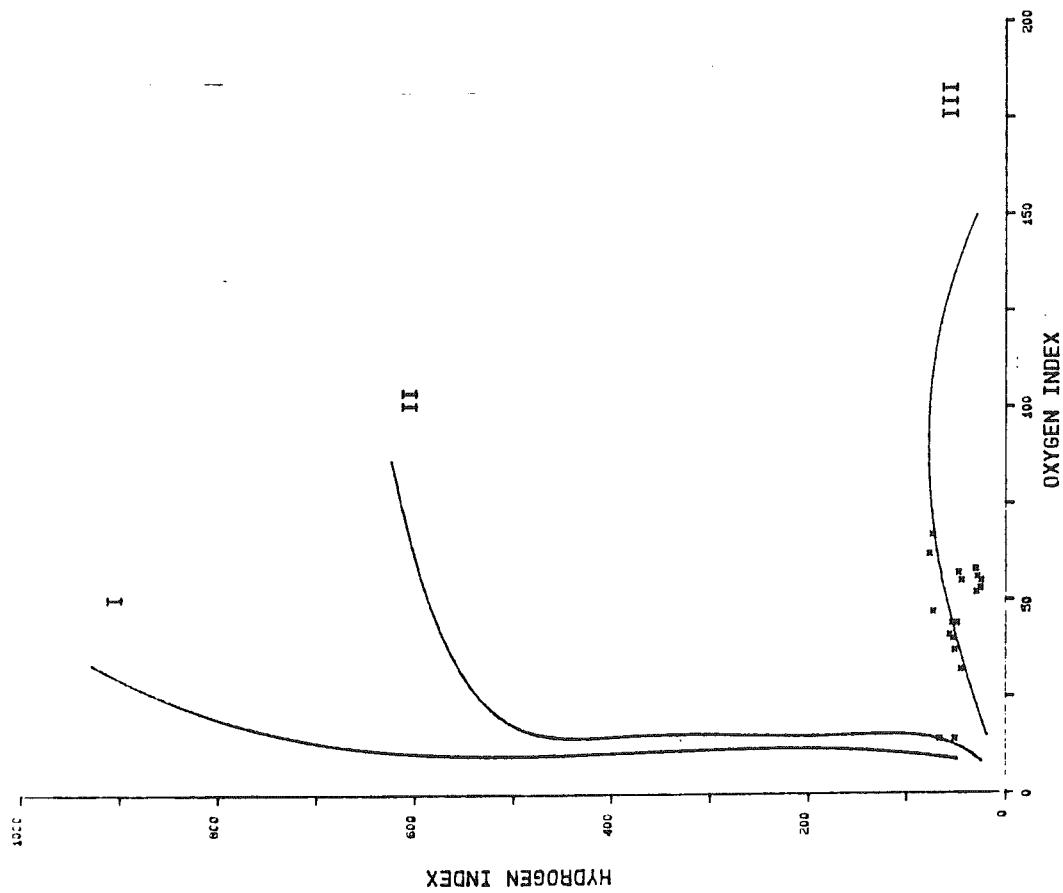


Figure 2b

COHASSET L-37

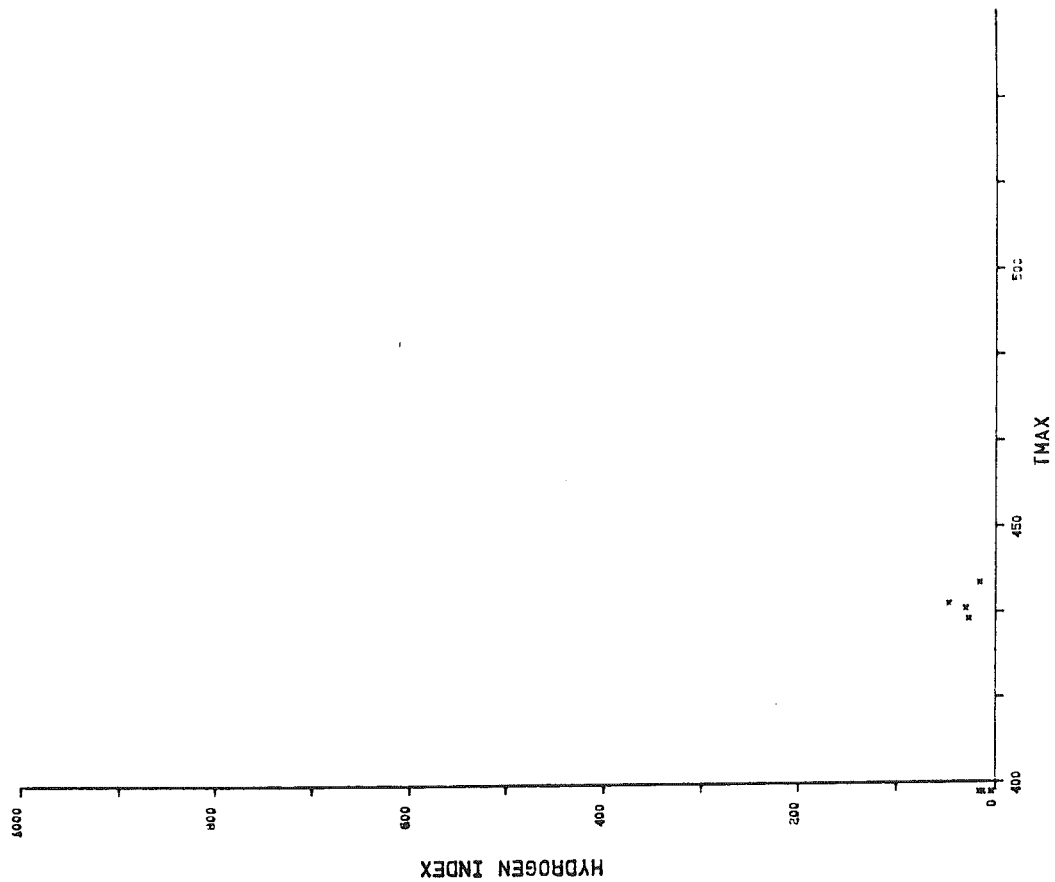
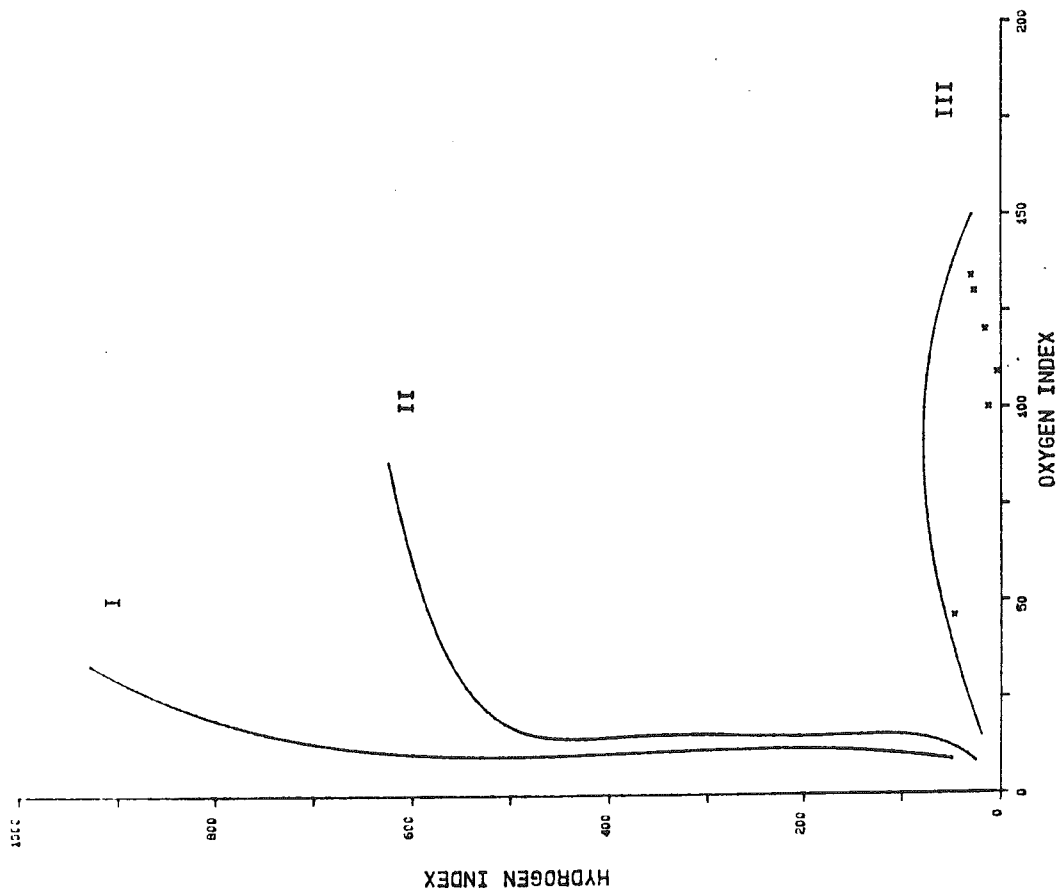


Figure 2c

CREE E-35

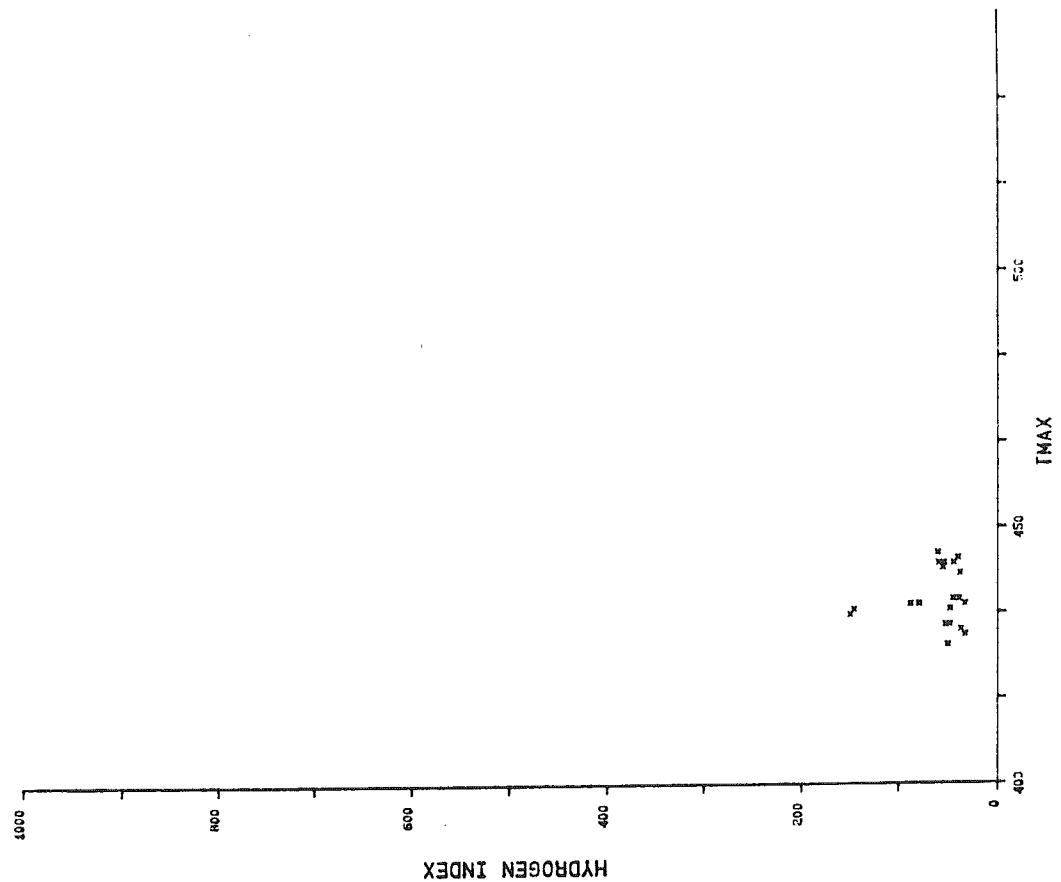
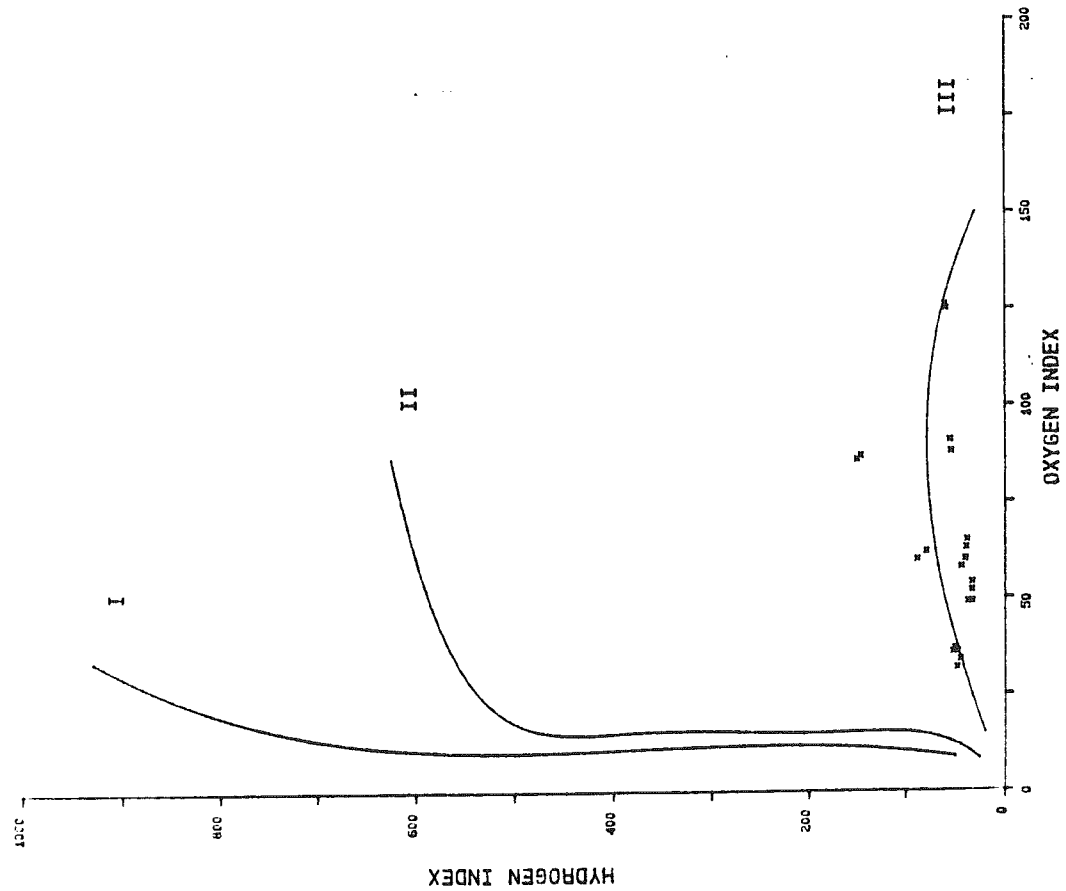


Figure 2d

DEMOSCOTA 6-32

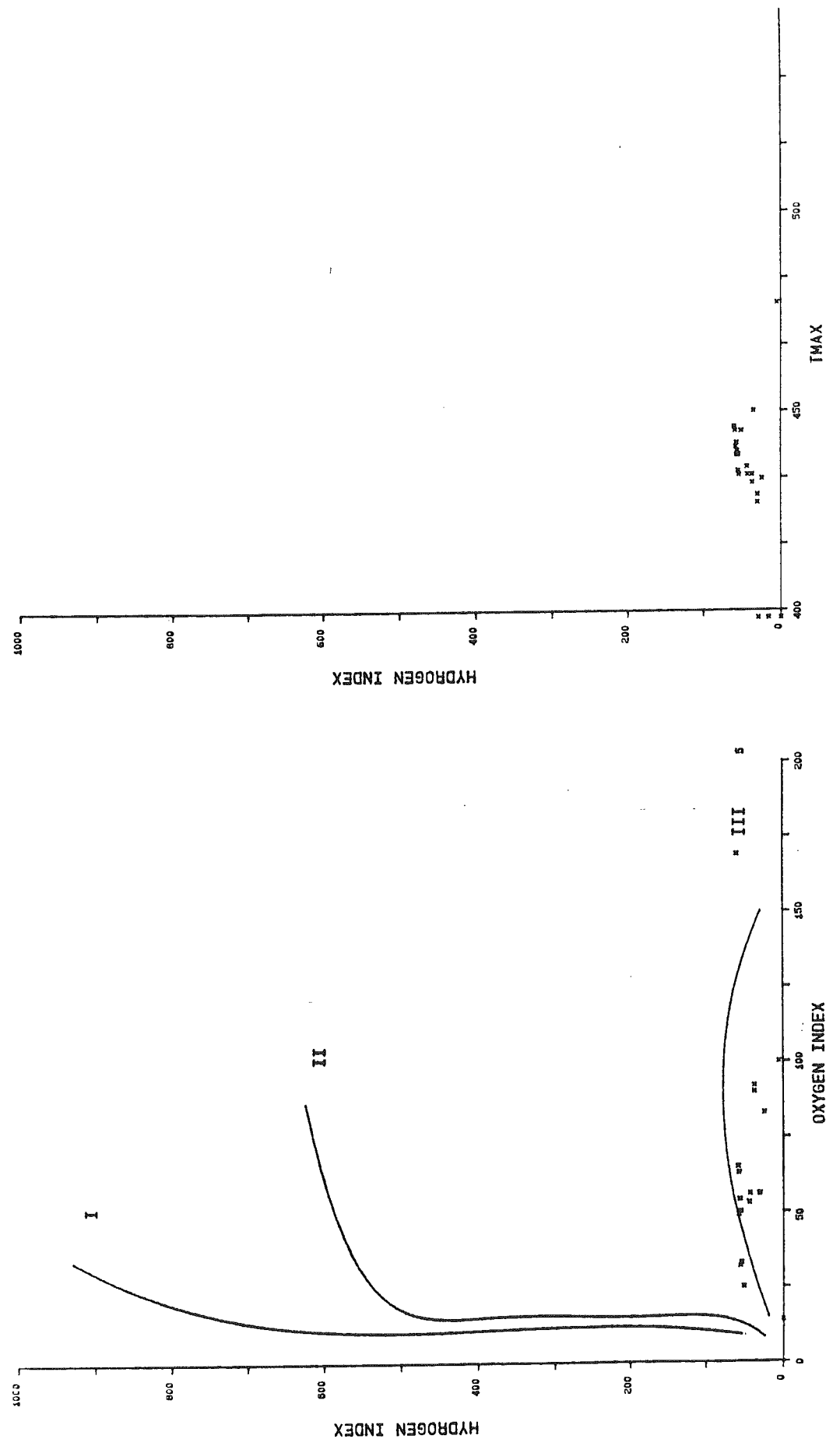


Figure 2e

# MIGRANT N-20

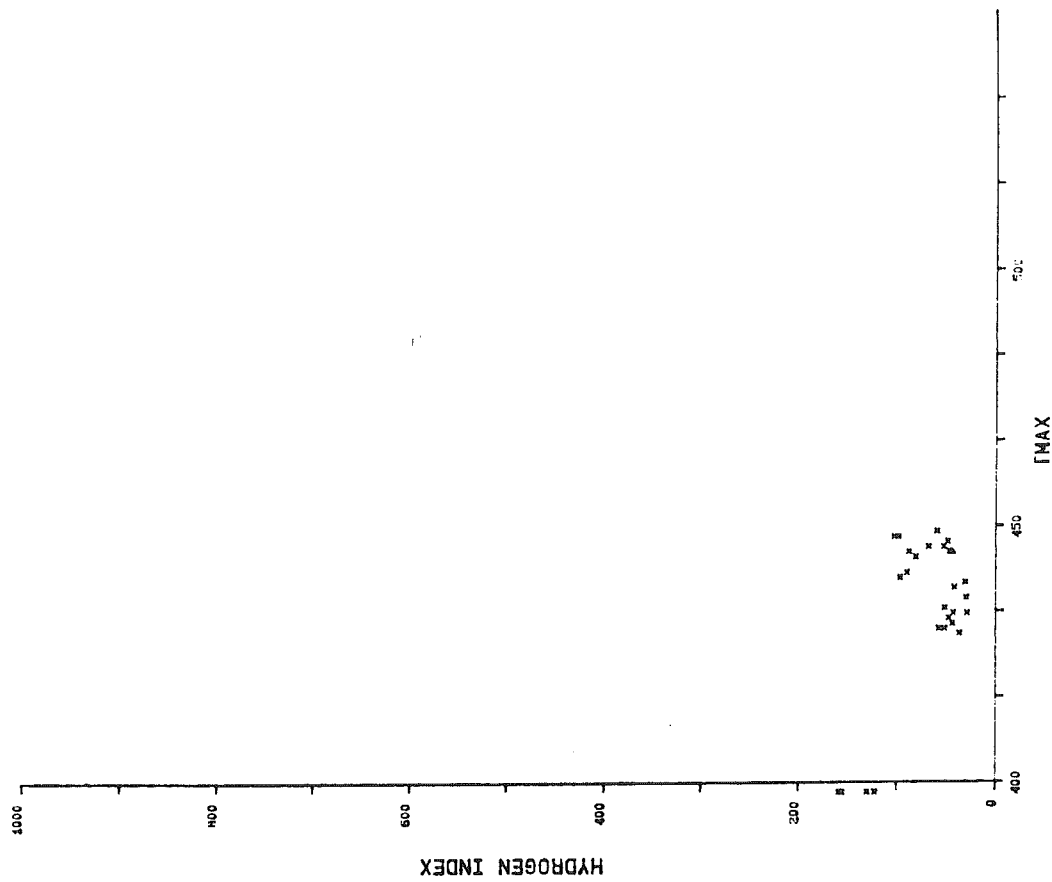
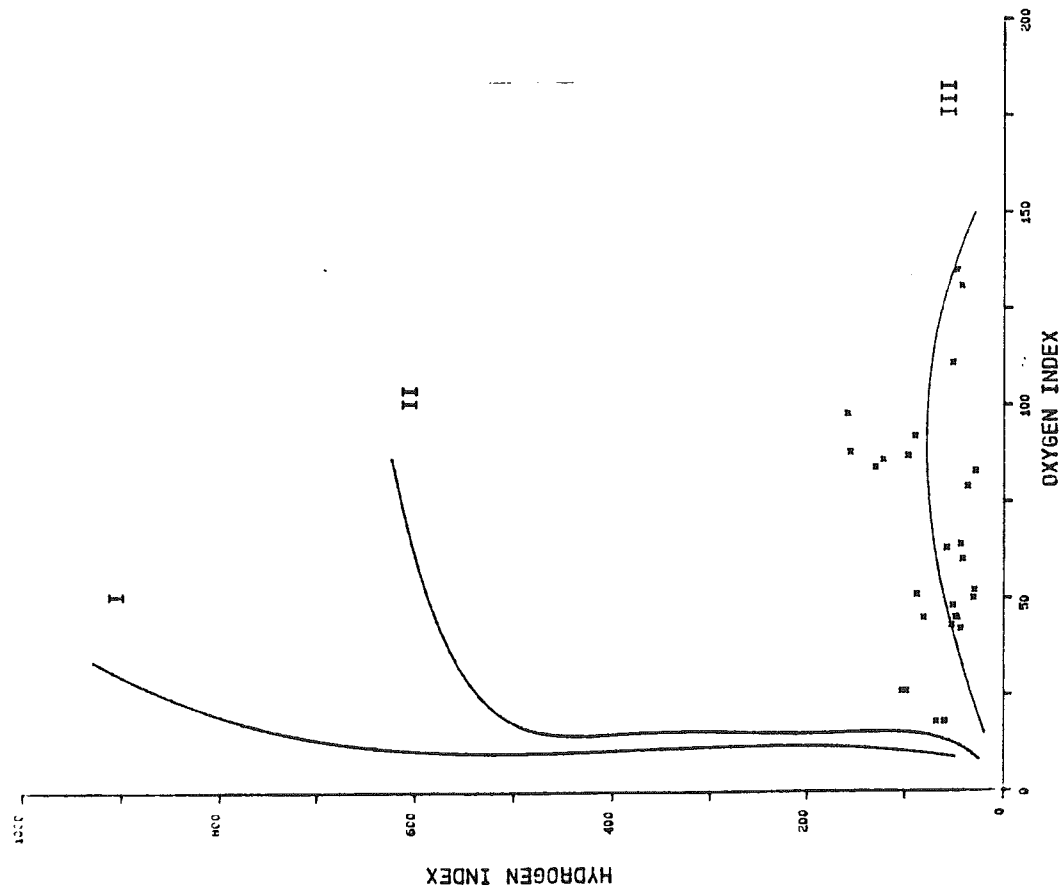


Figure 2f



NORTH TRIUMPH B-52

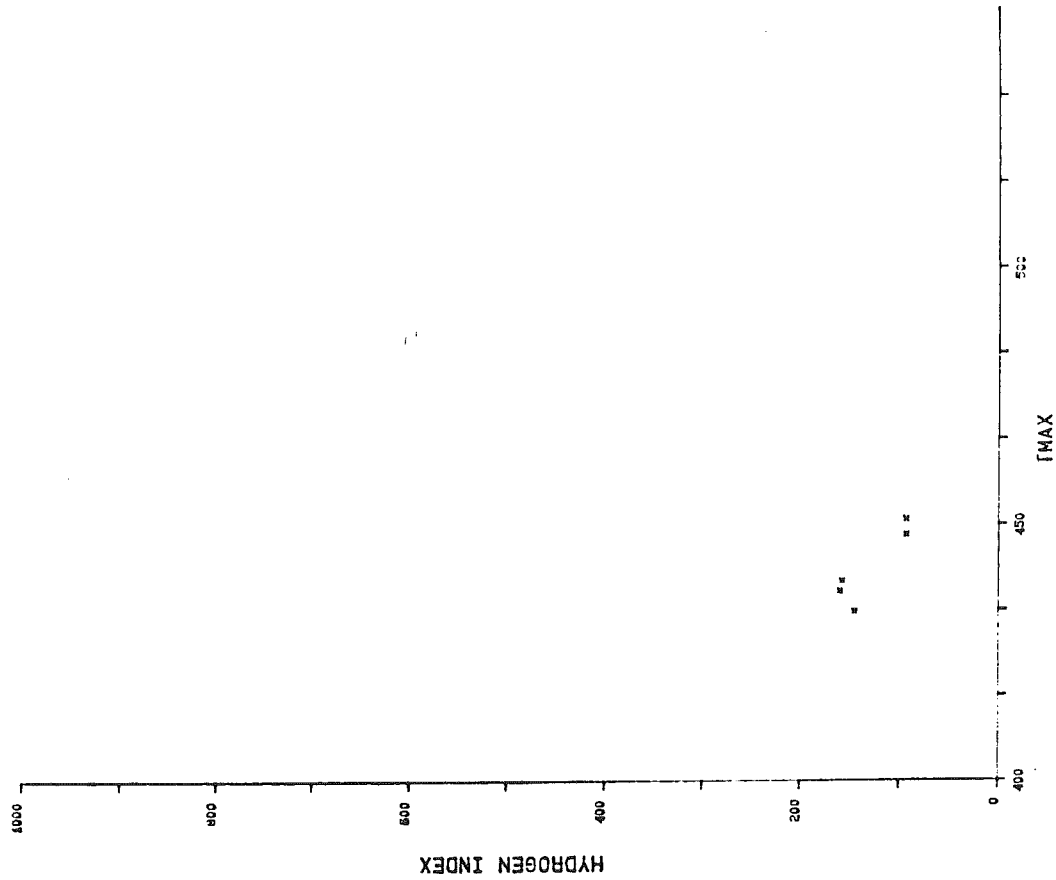
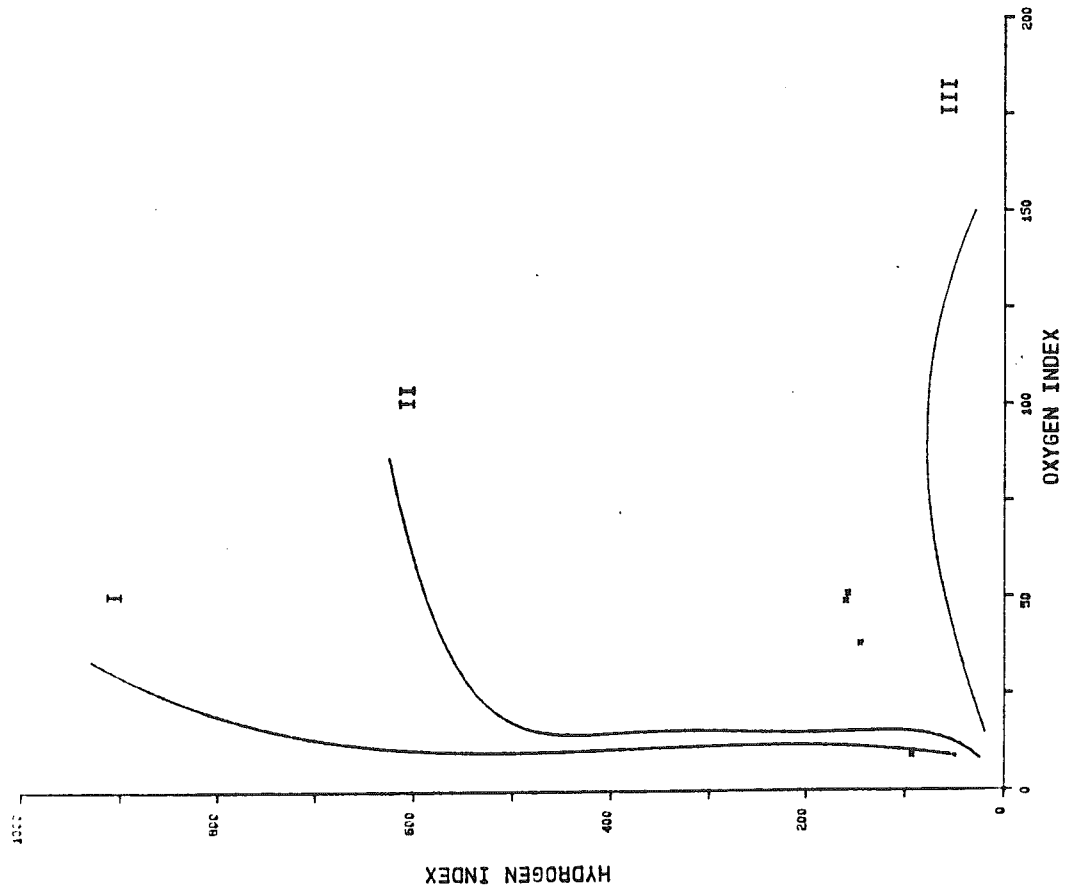


Figure 2g

# NORTH TRIUMPH G-43

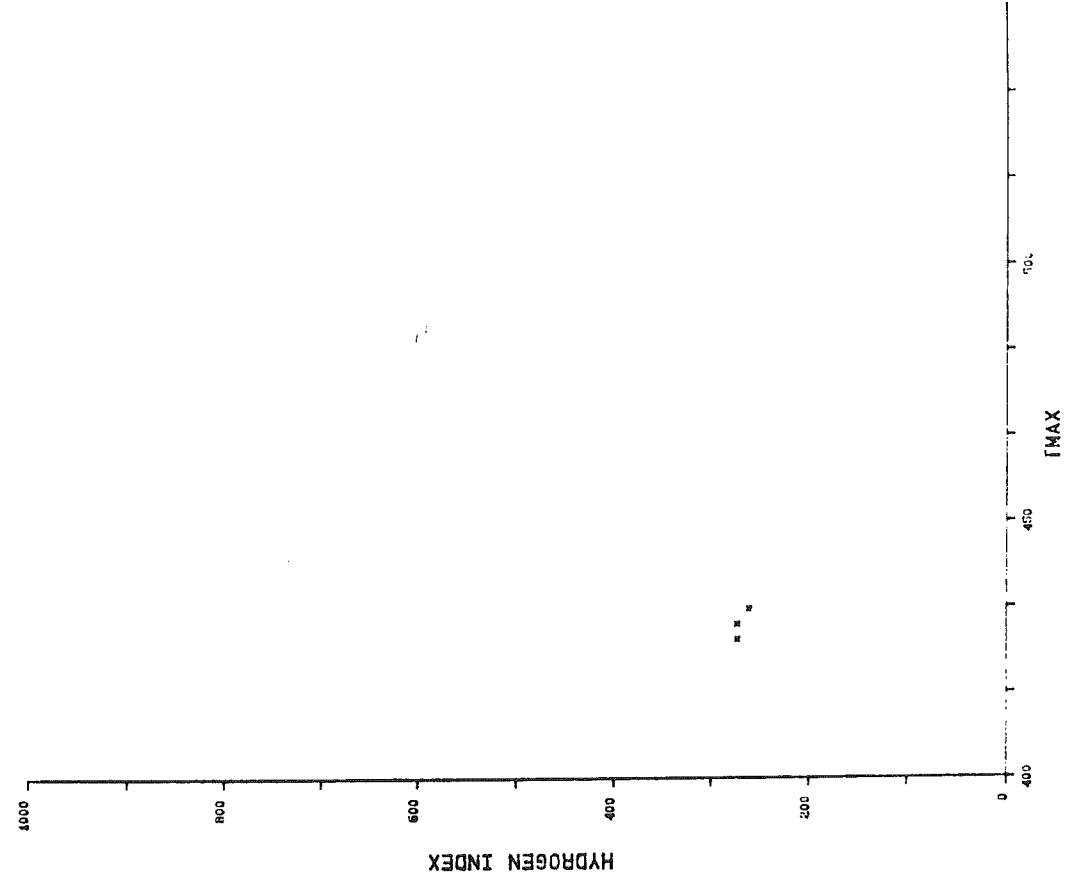
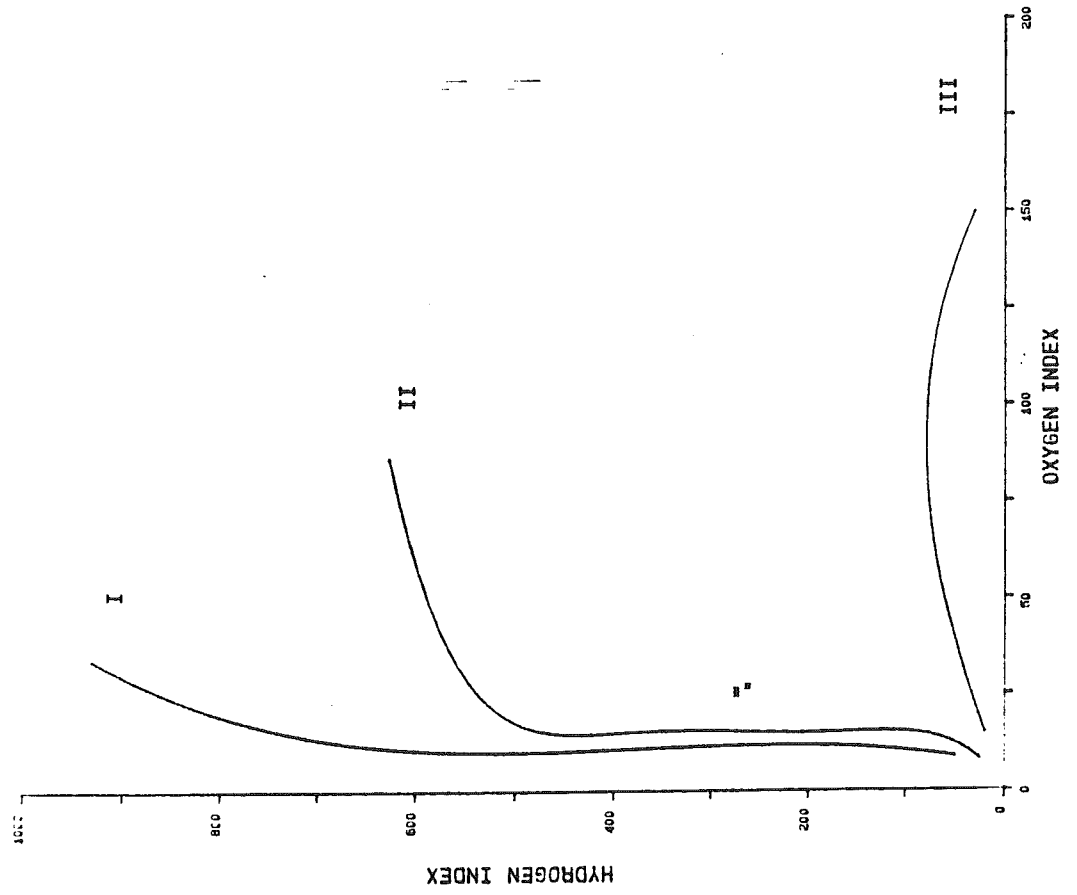
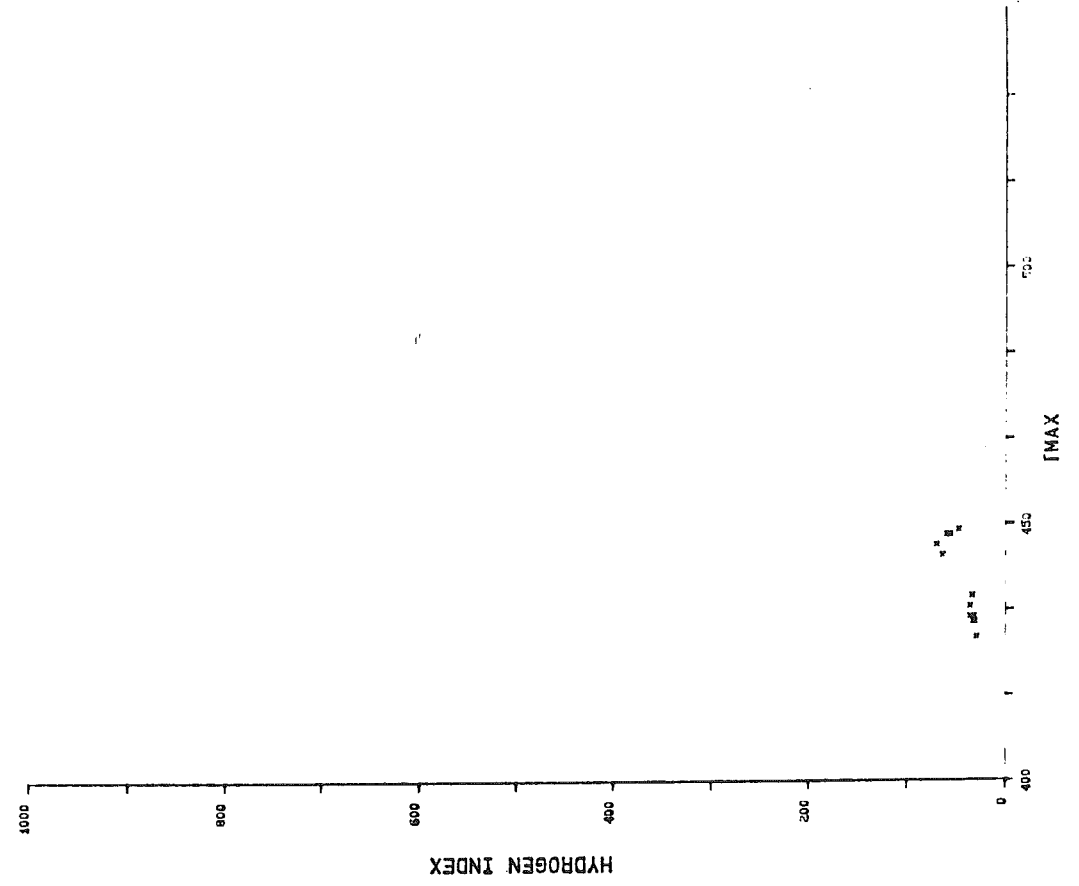
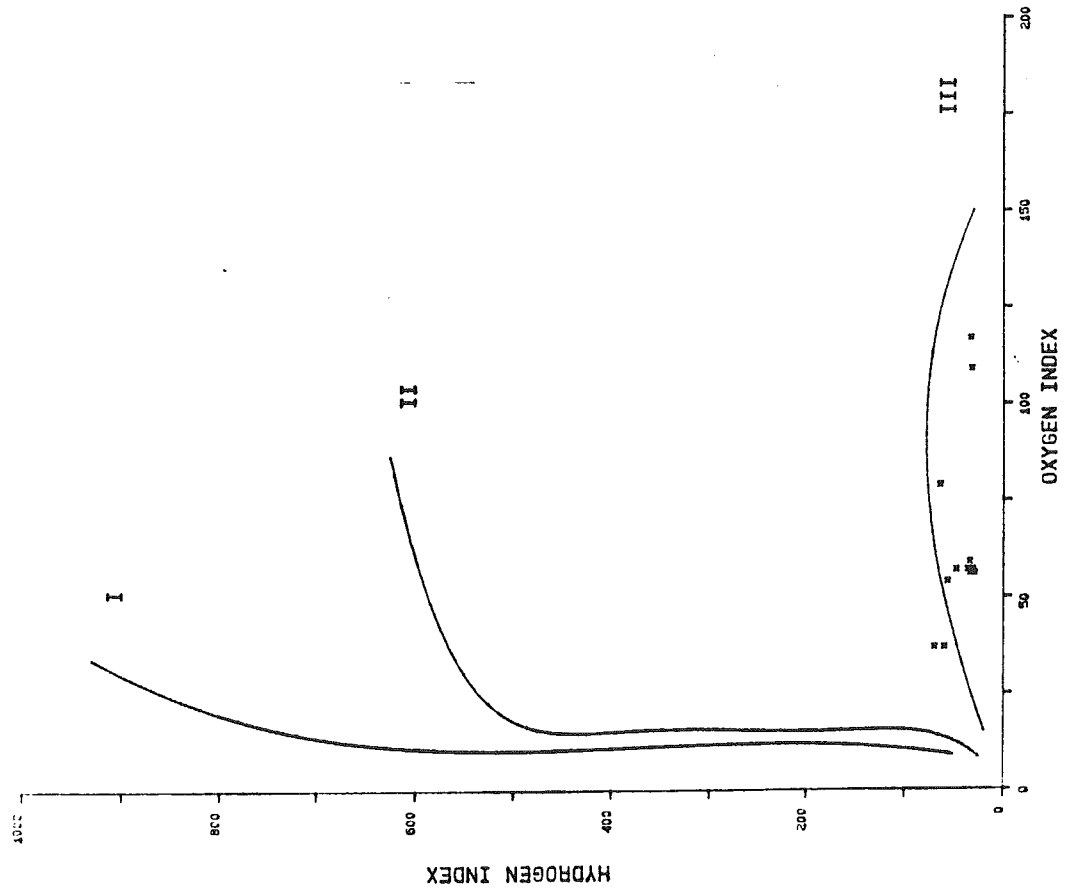


Figure 2h

# OLYMPIA A-12



ONONDAGA E-84

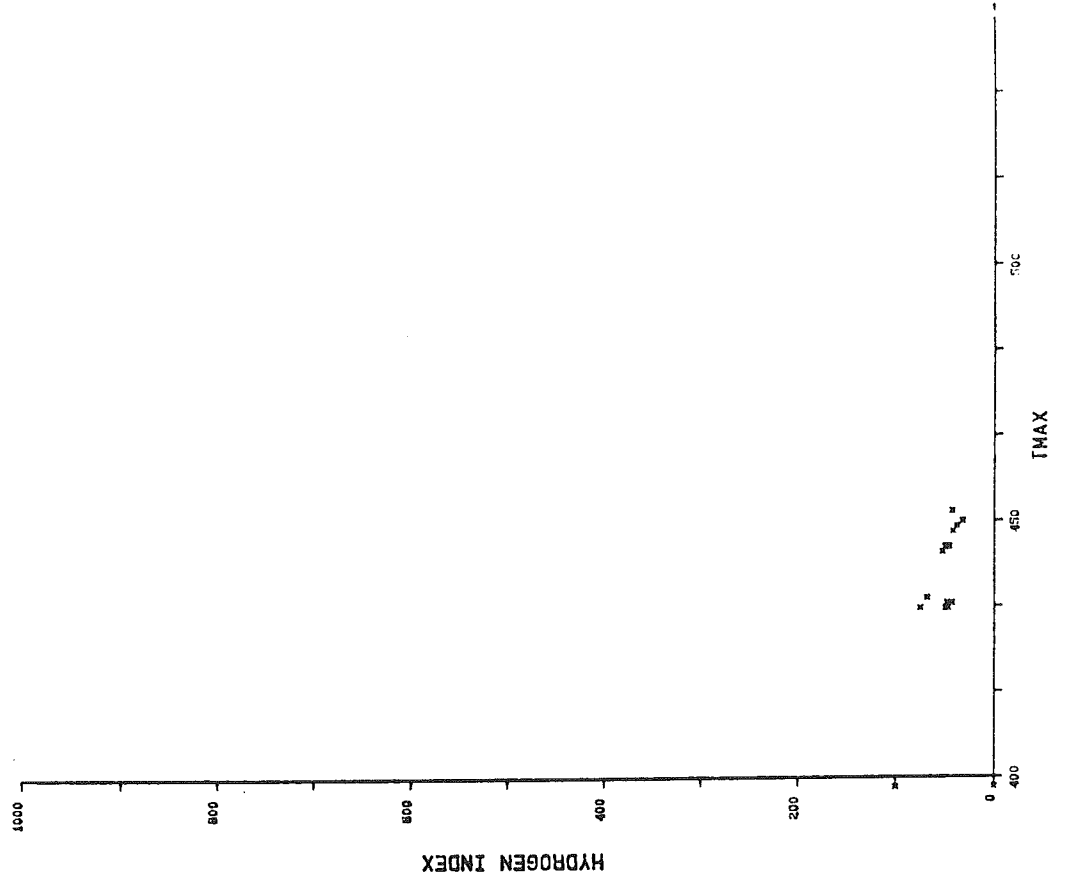
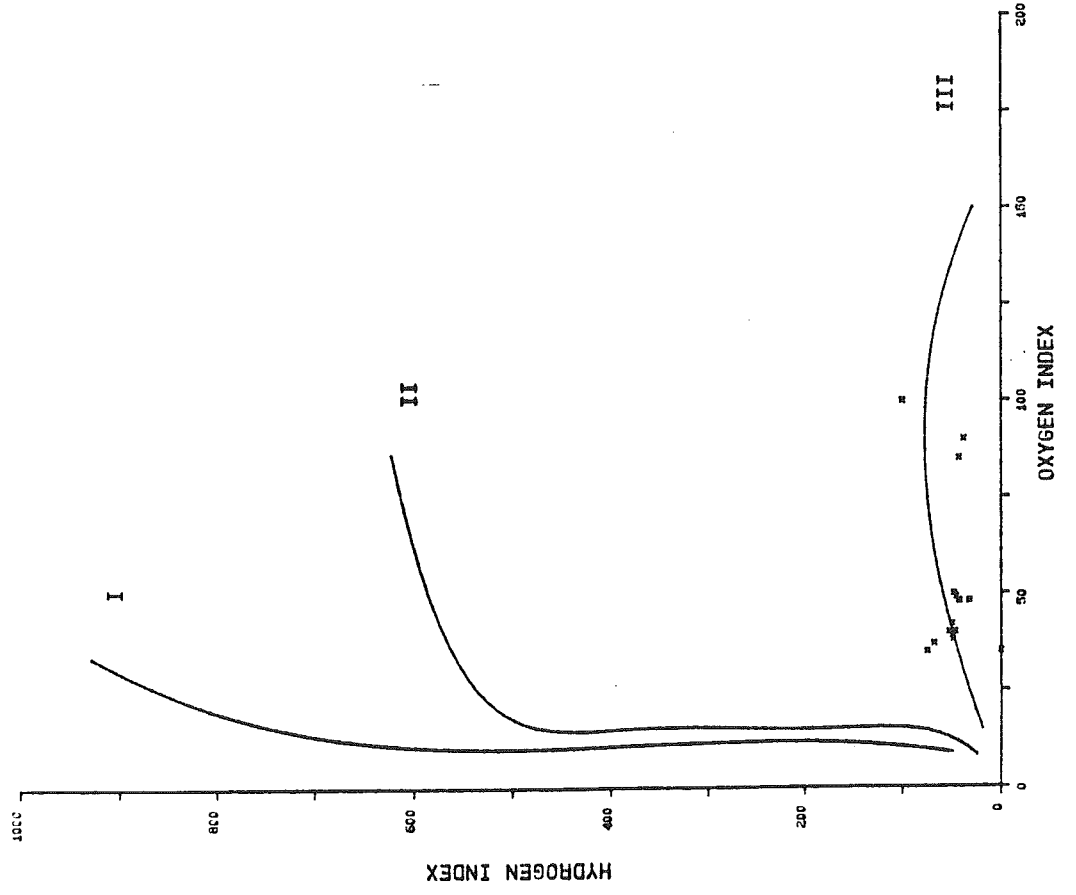


Figure 2j

# PENOBSCOT L-30

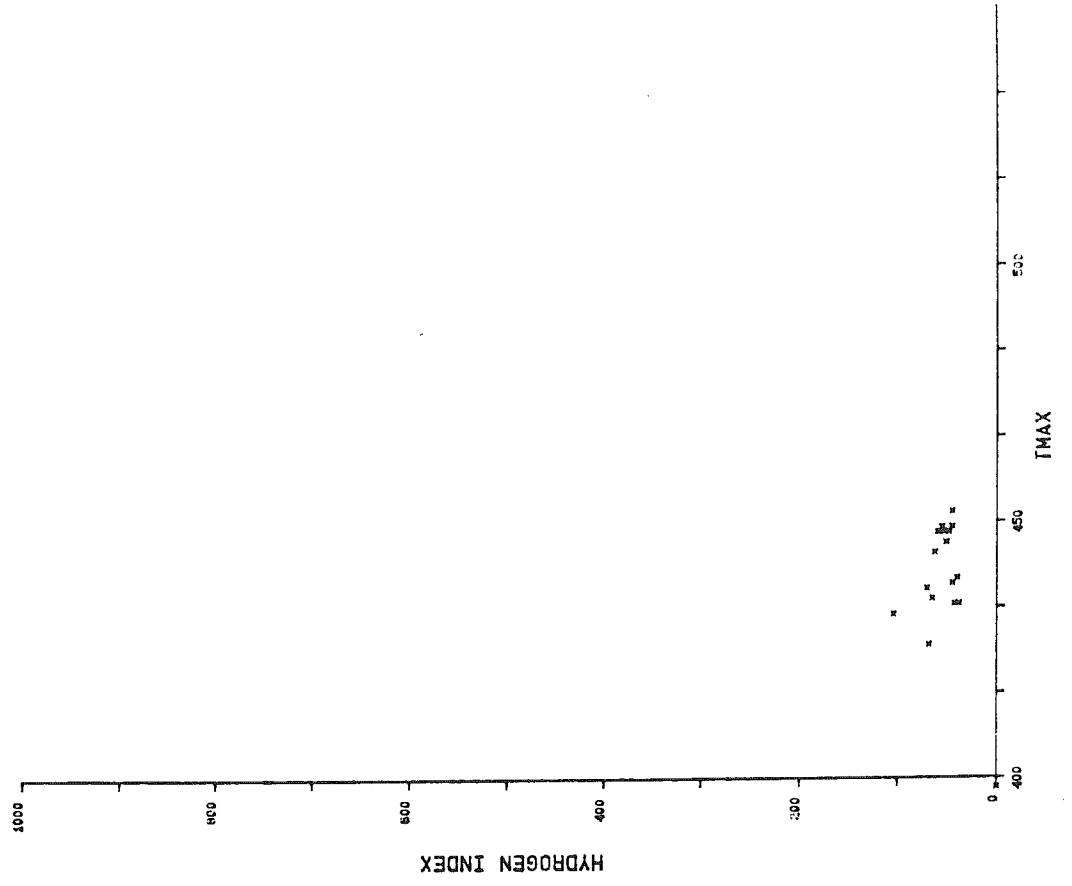
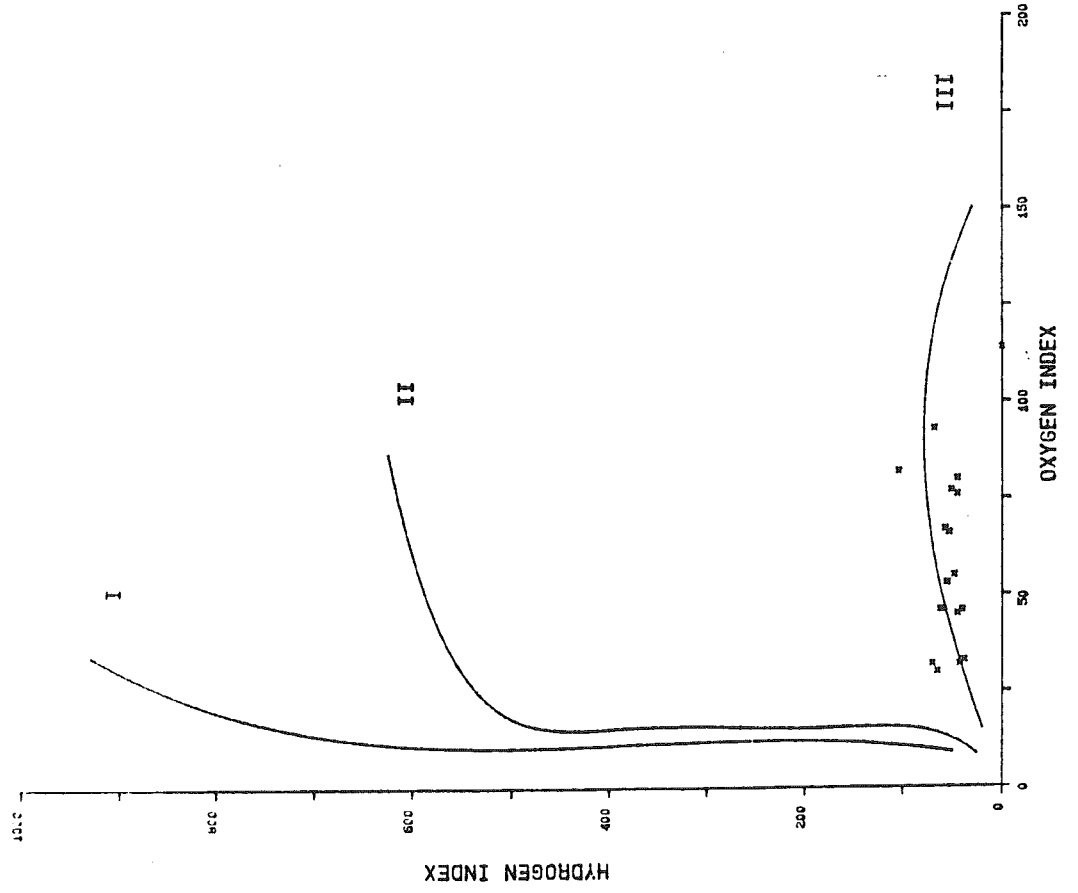


Figure 2k

# SABLE ISLAND E-48

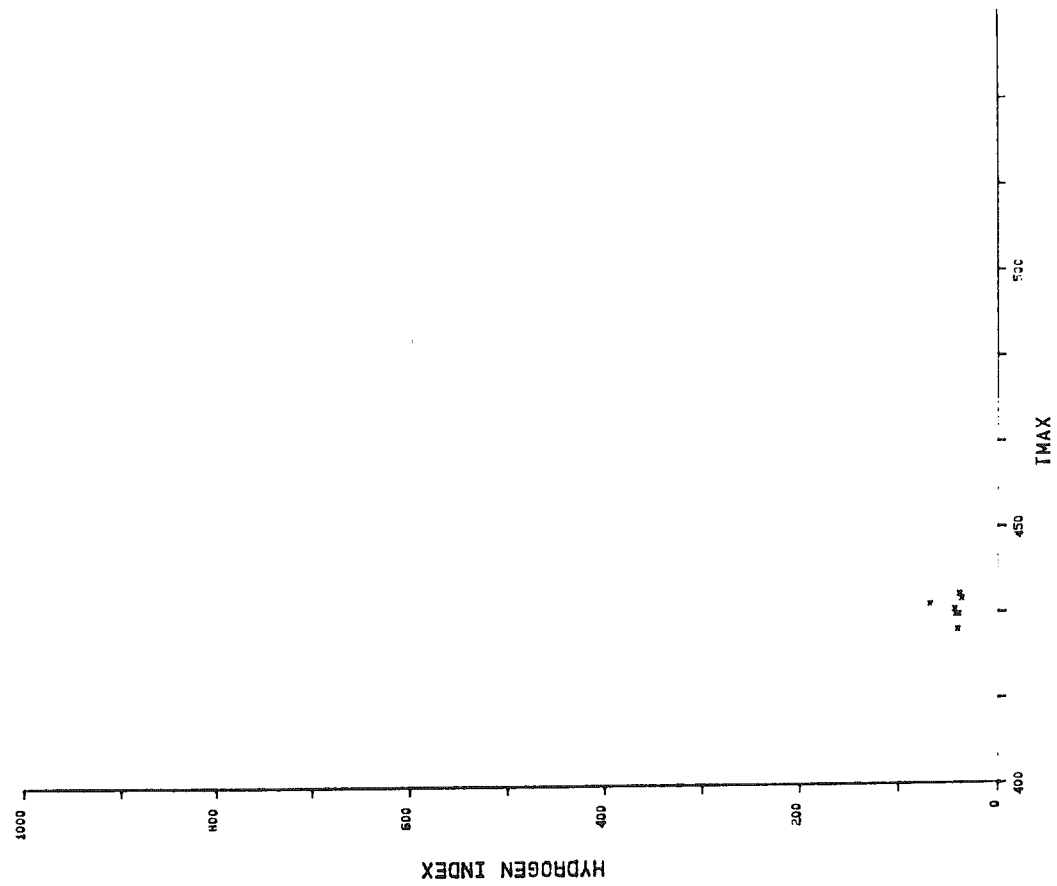
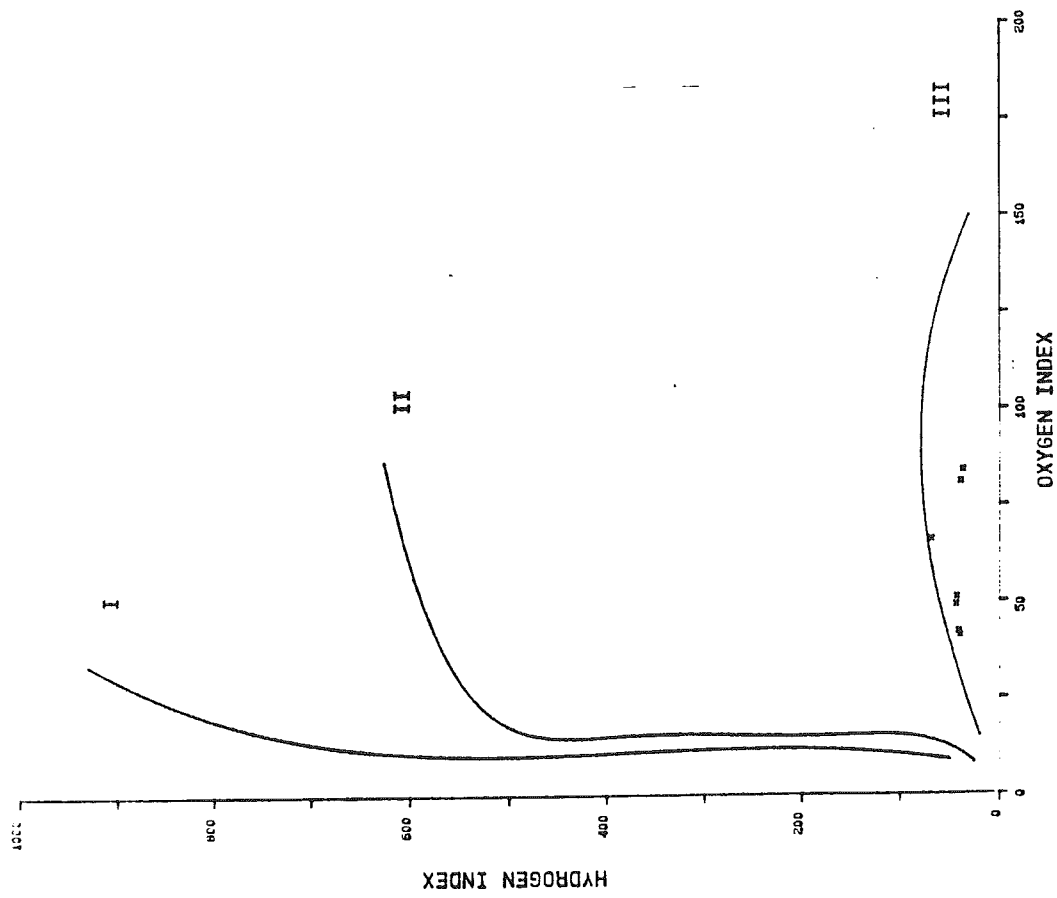


Figure 21

# SABLE ISLAND 0-47

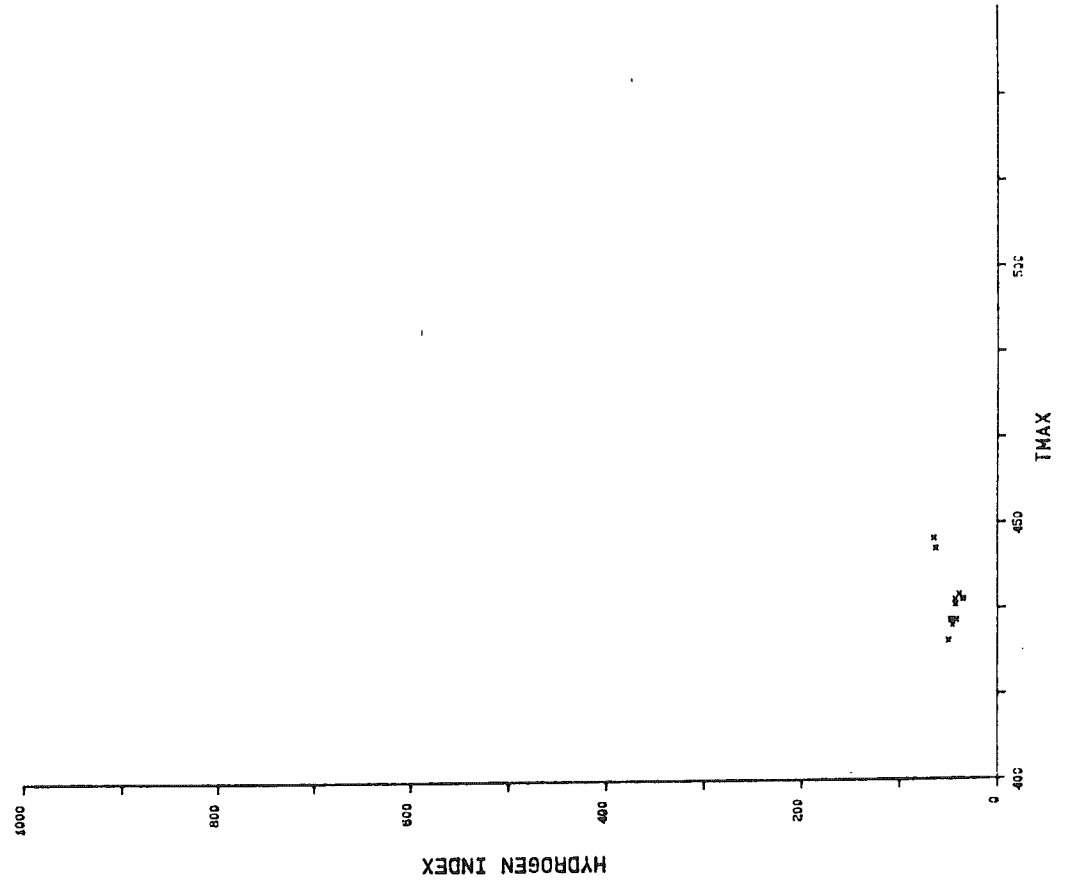
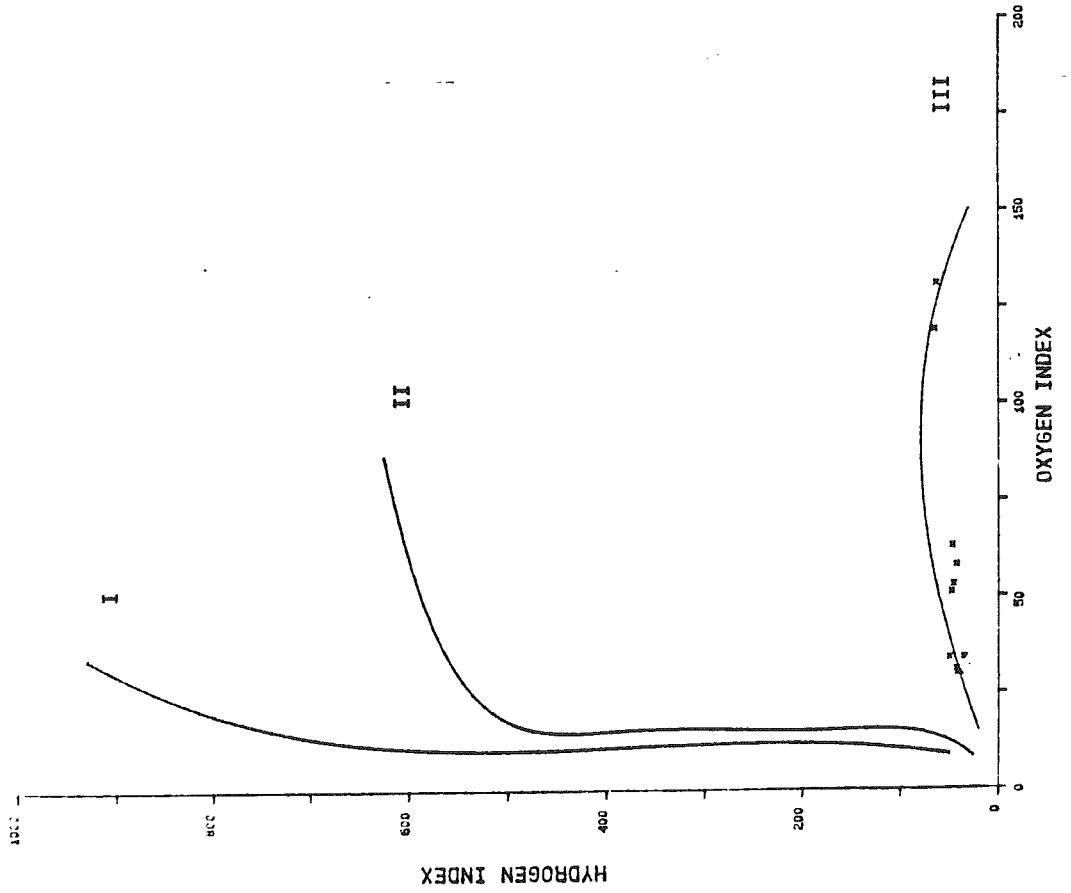


Figure 2m

# SOUTH DESBERRES 0-76

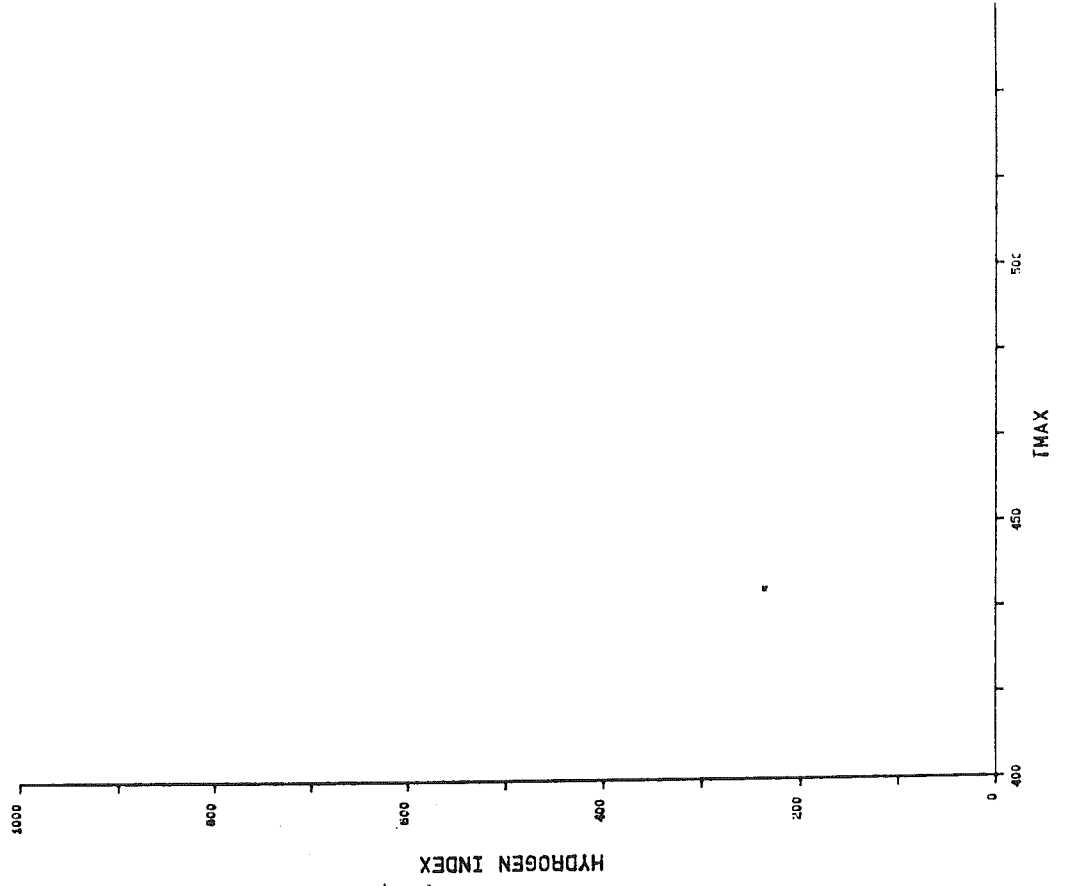
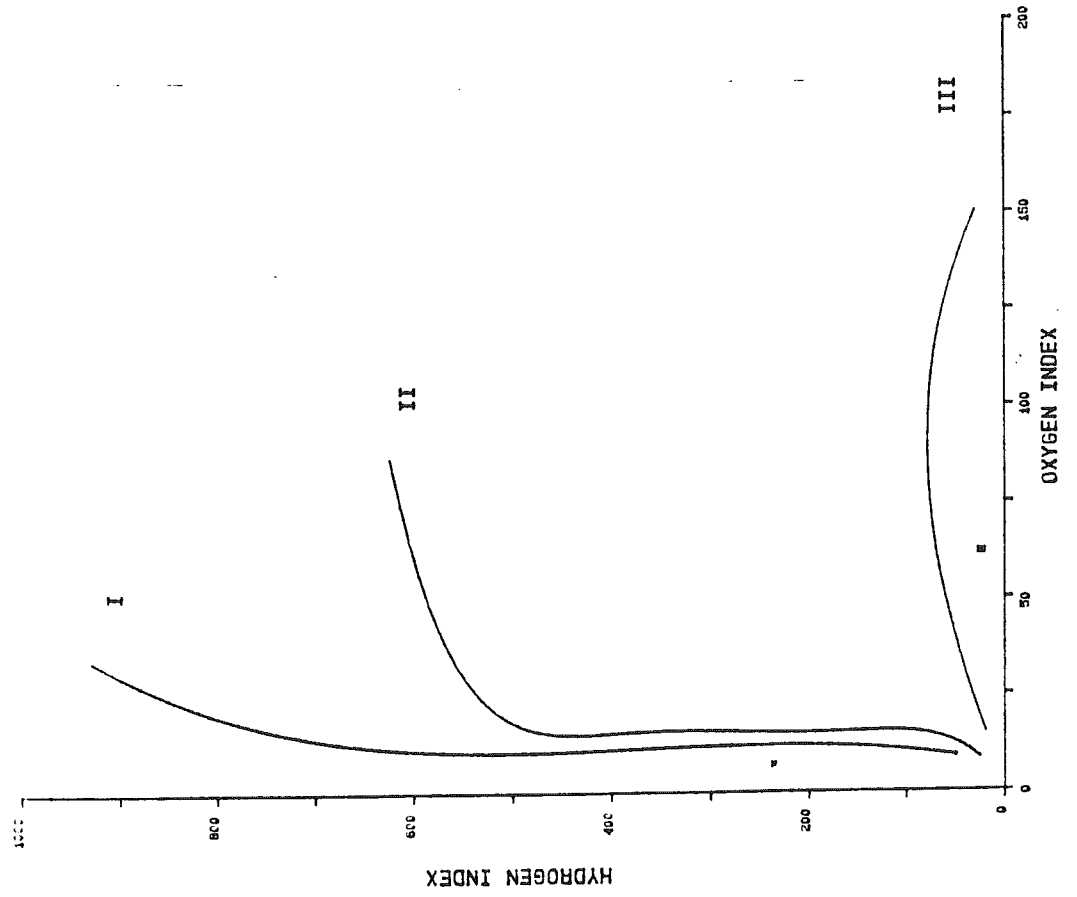


Figure 2n



# SOUTH SABLE B-44

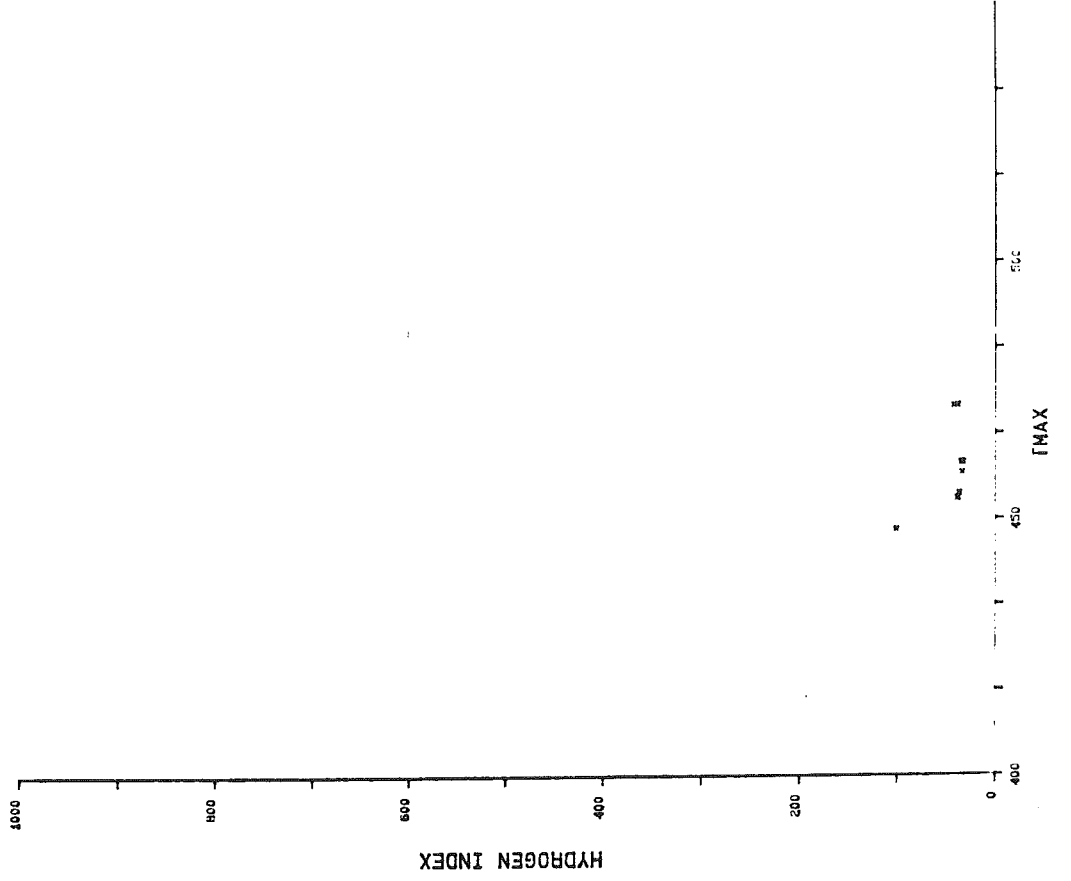
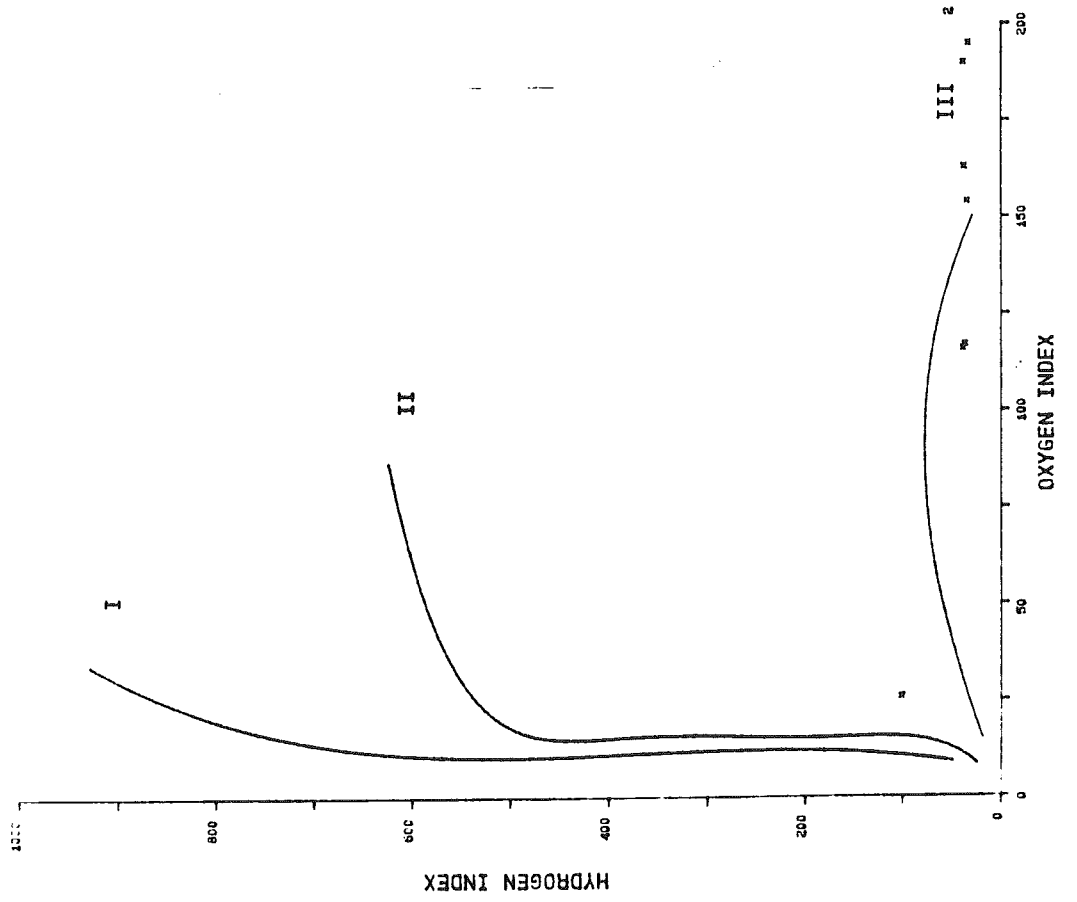


Figure 20

# THEBAUD C-74

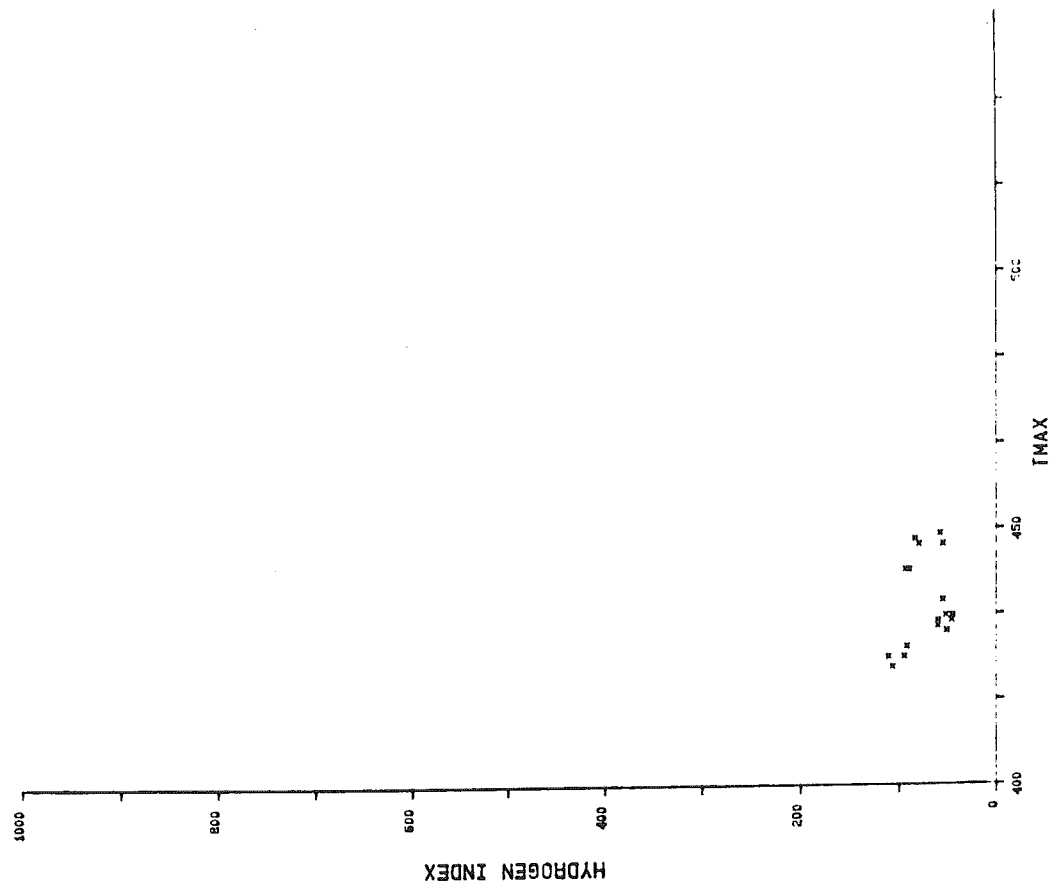
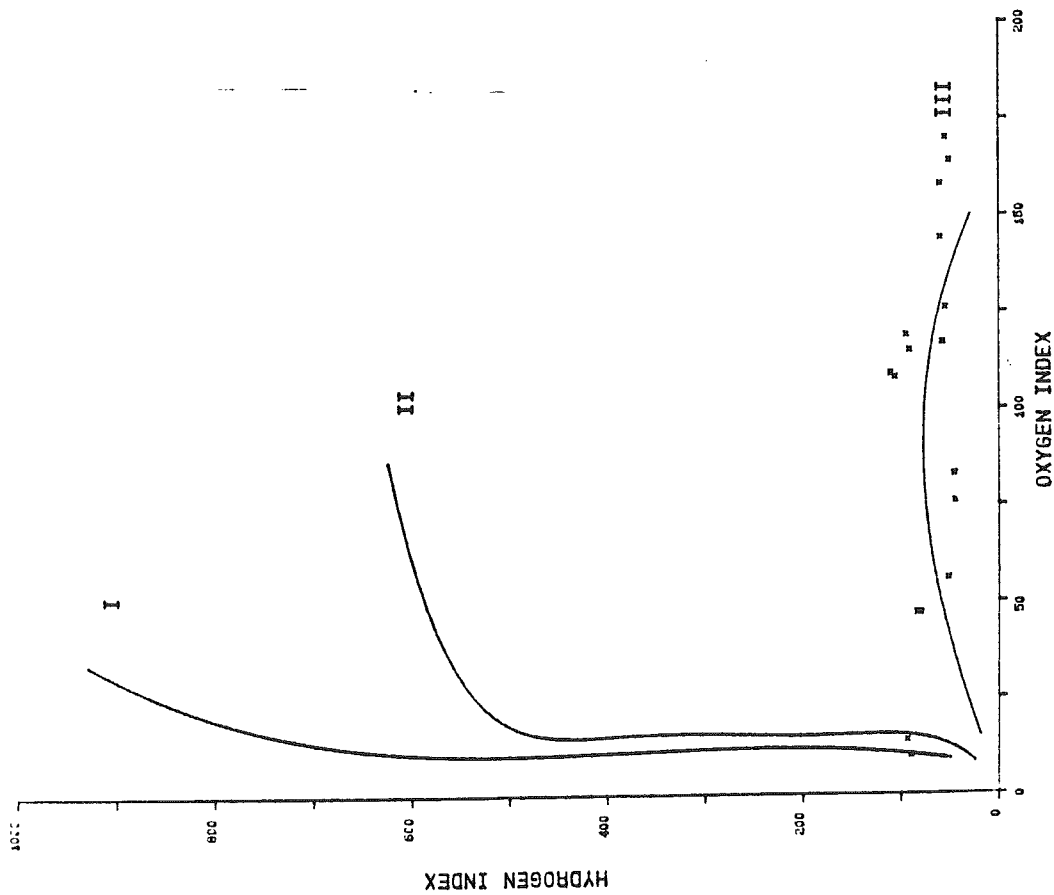


Figure 2p

# UNIACKE G-72

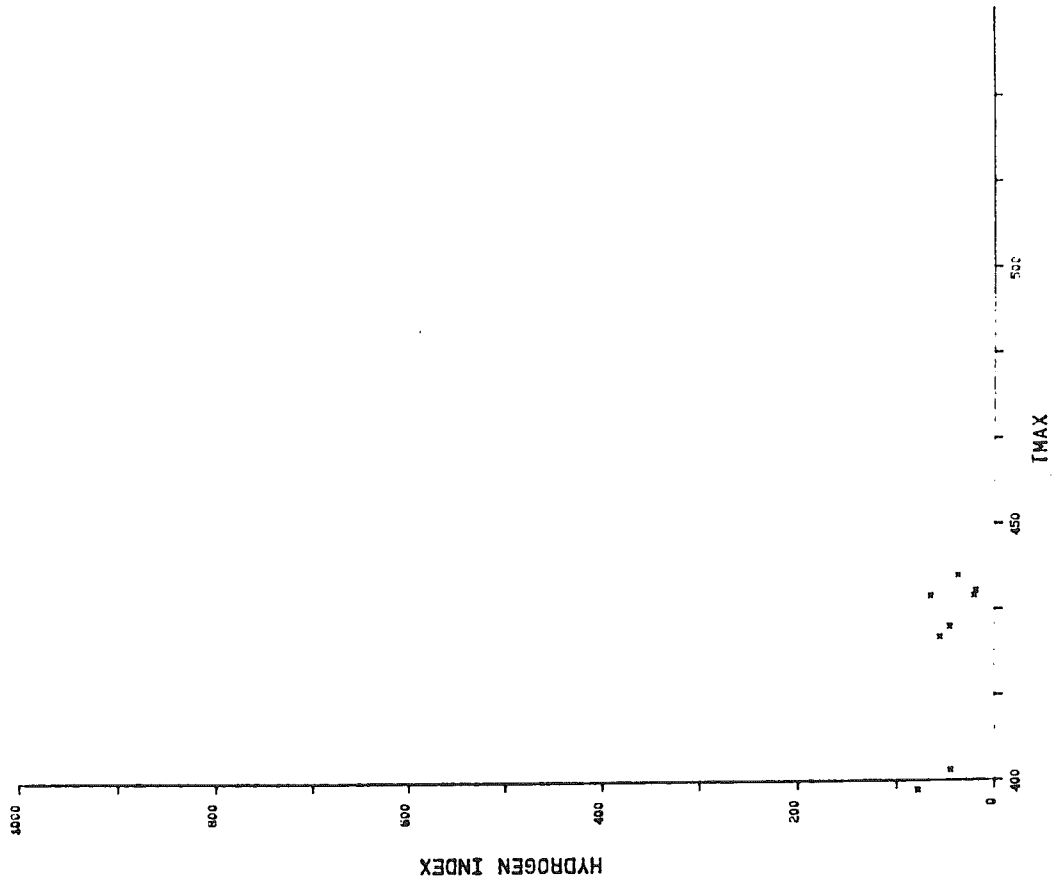
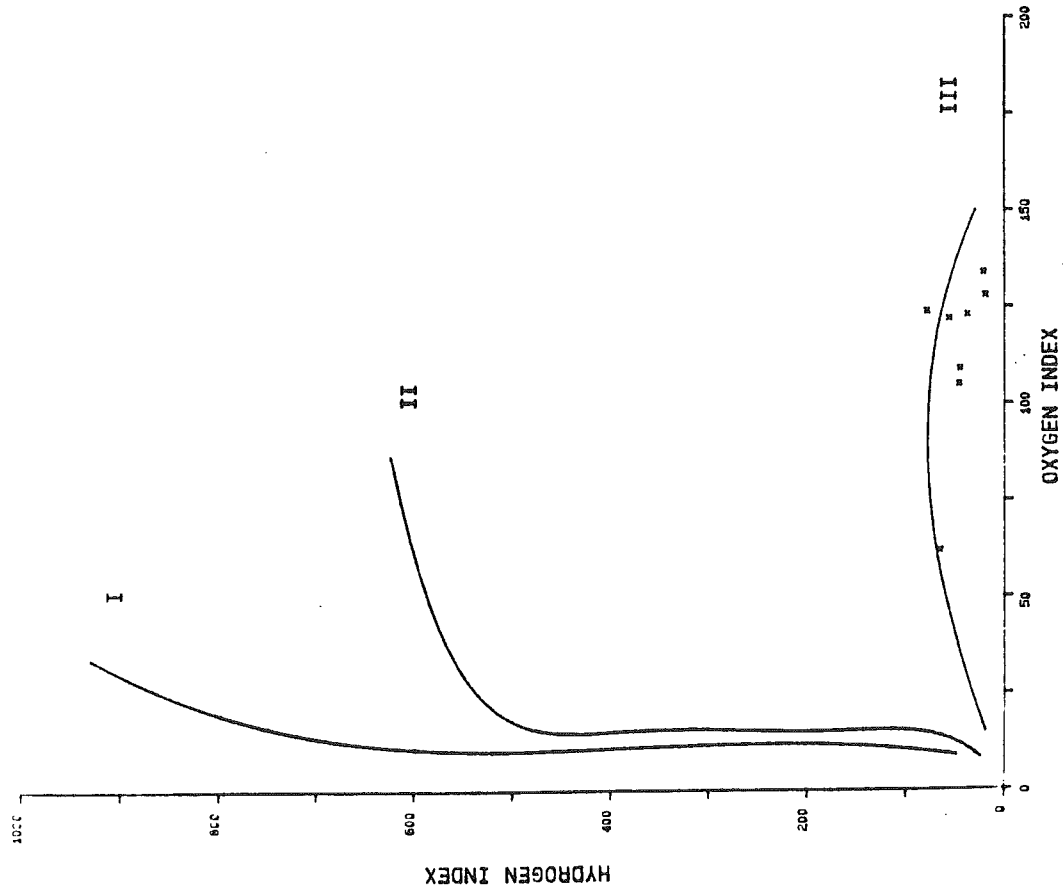


Figure 2q

# VENTURE B-52

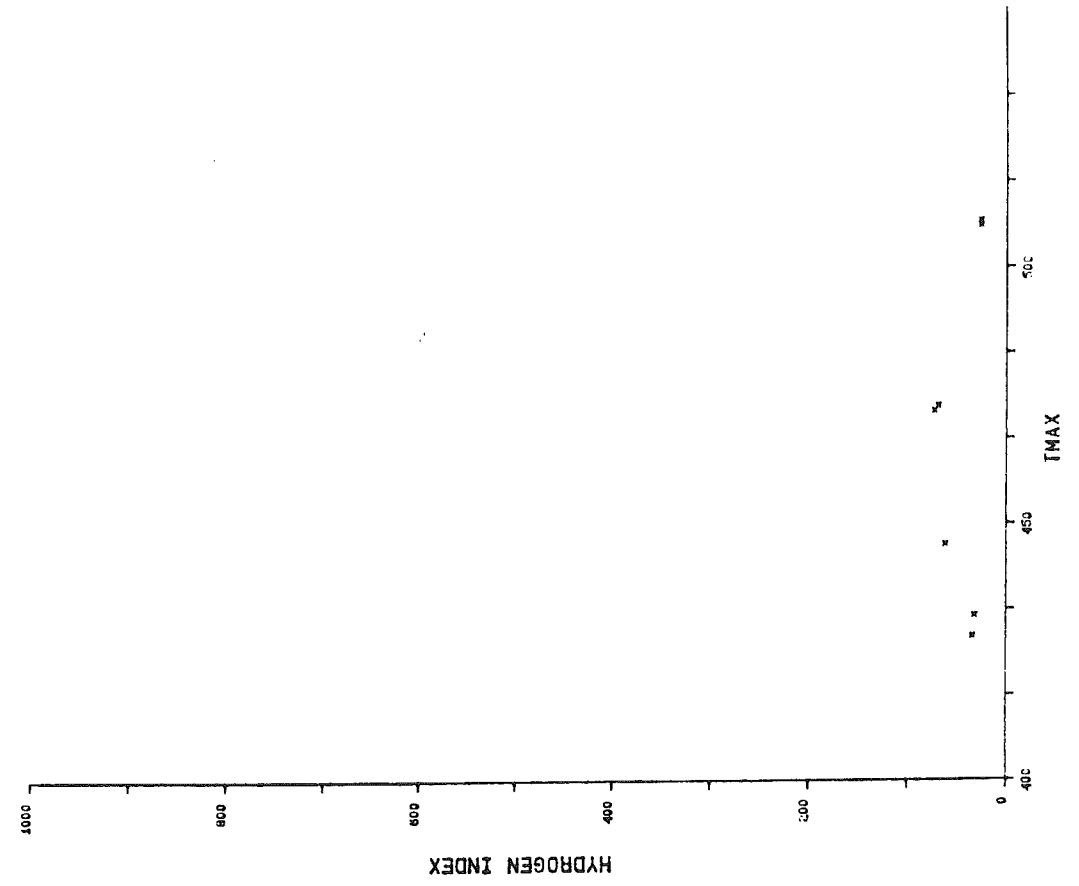
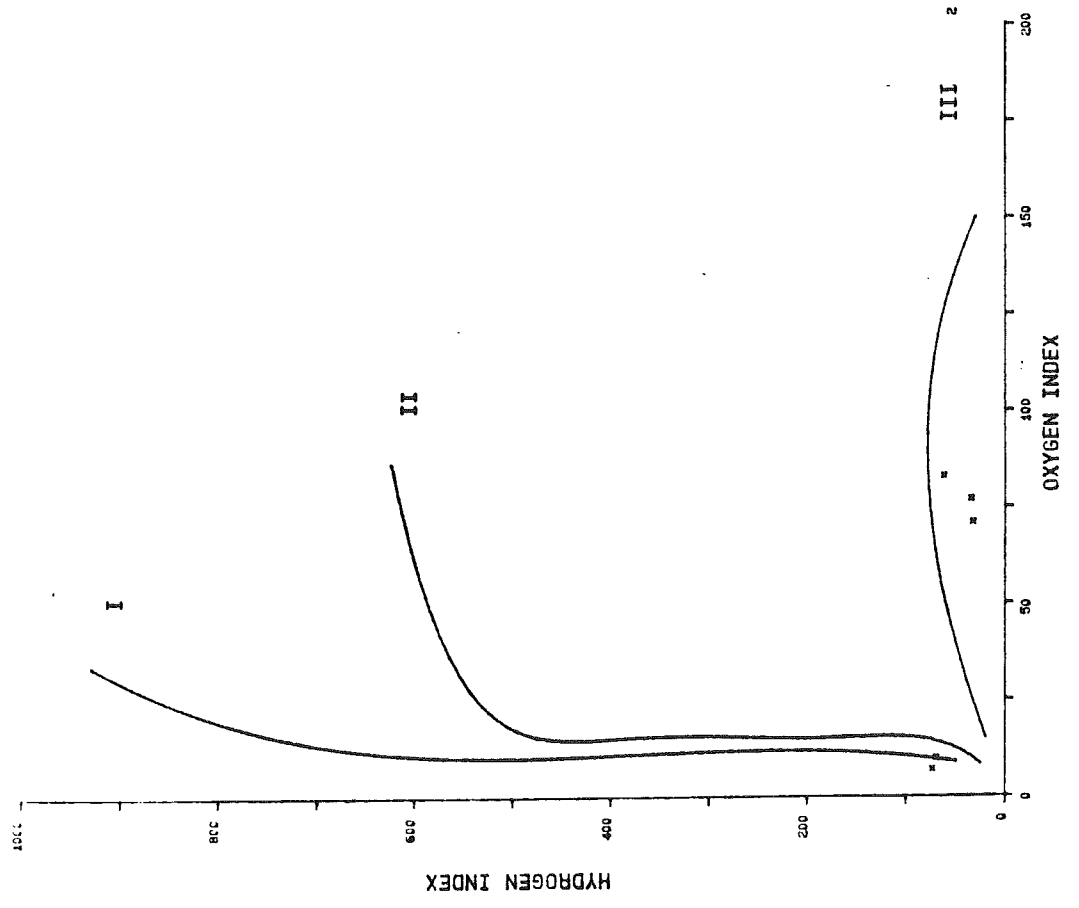


Figure 2r

# VENTURE H-22

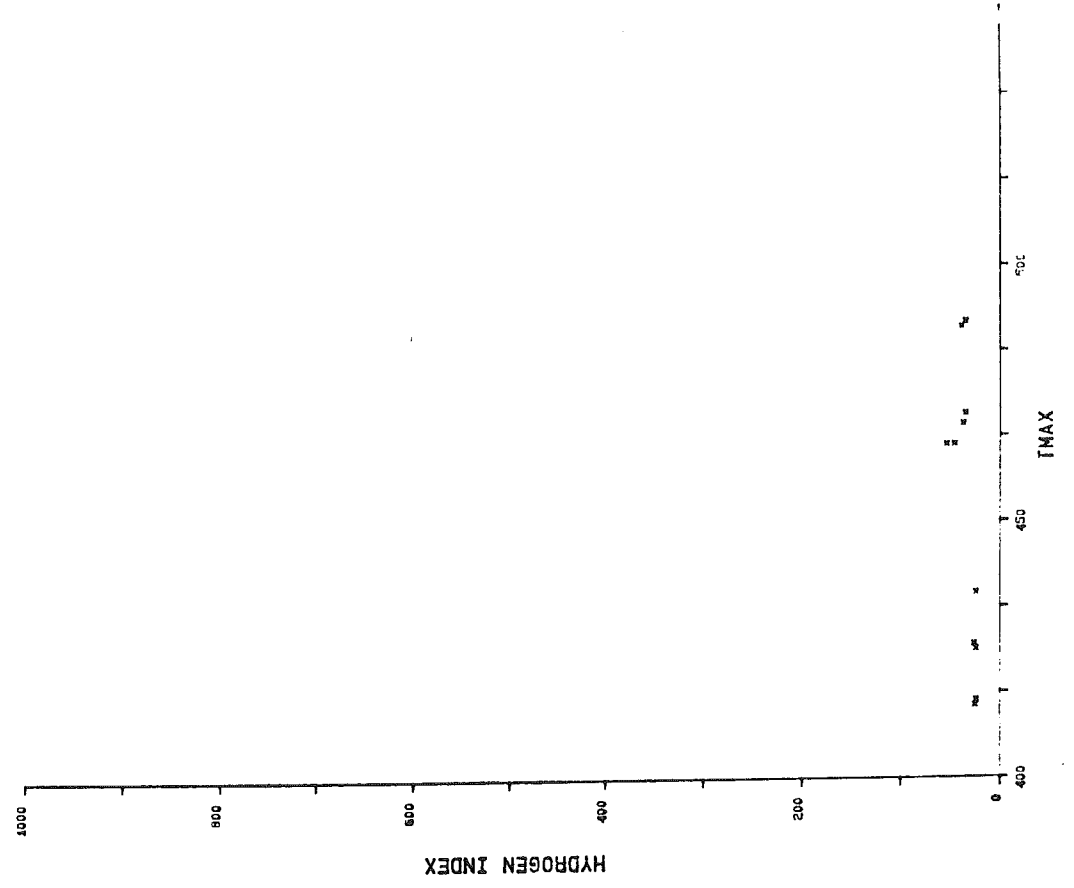
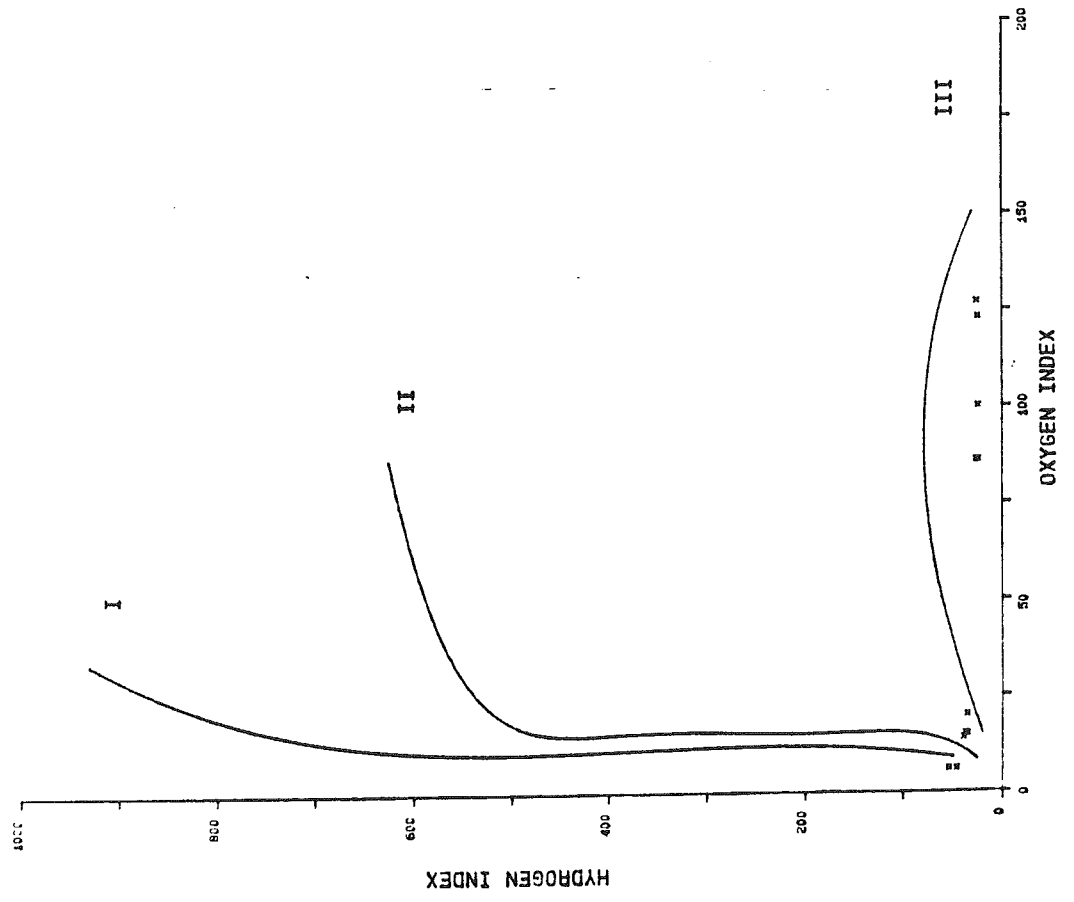


Figure 2s

# WEST CHEBUCTO K-20

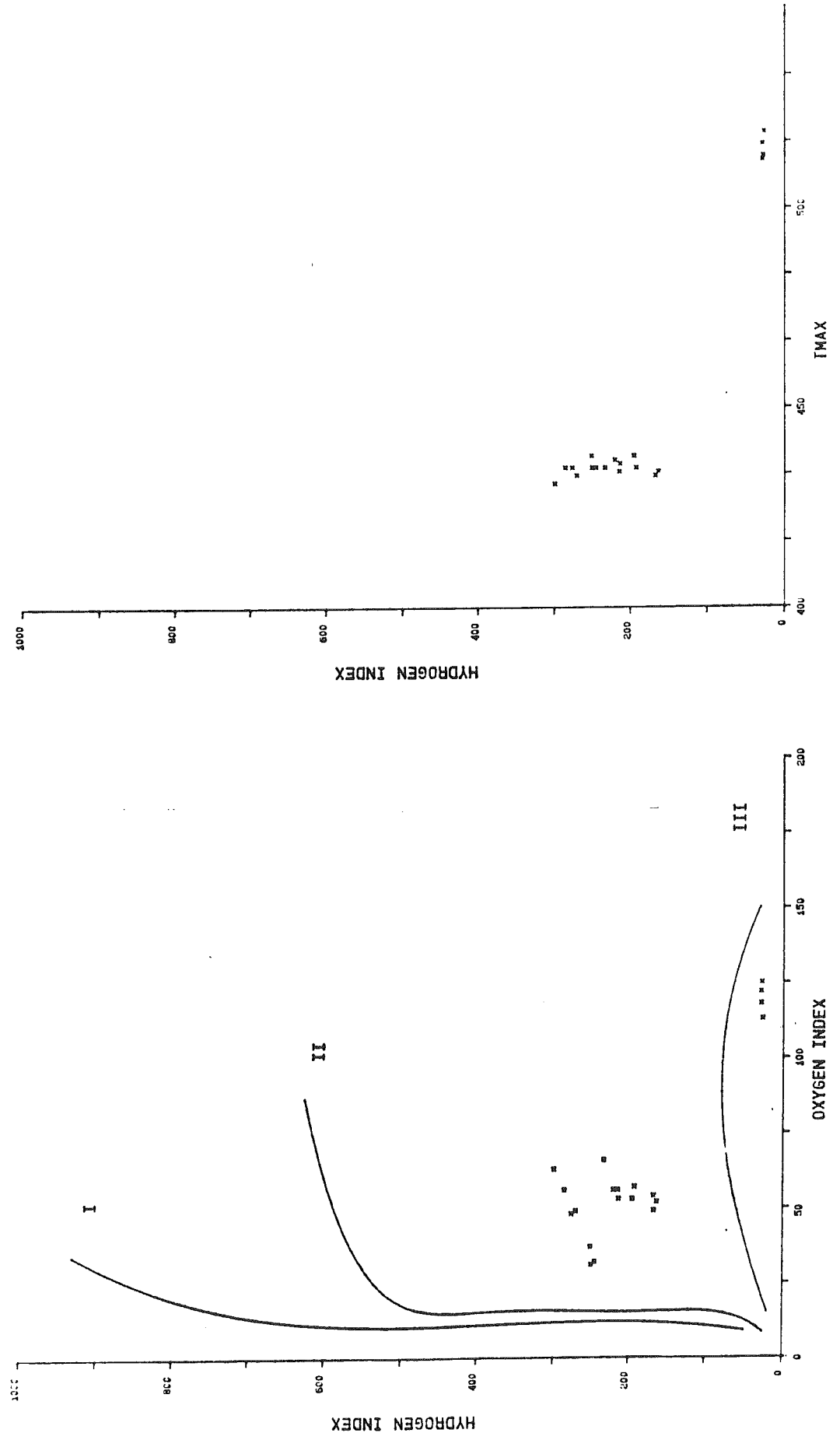


Figure 2t

# WHYCOCOMAGH N-90

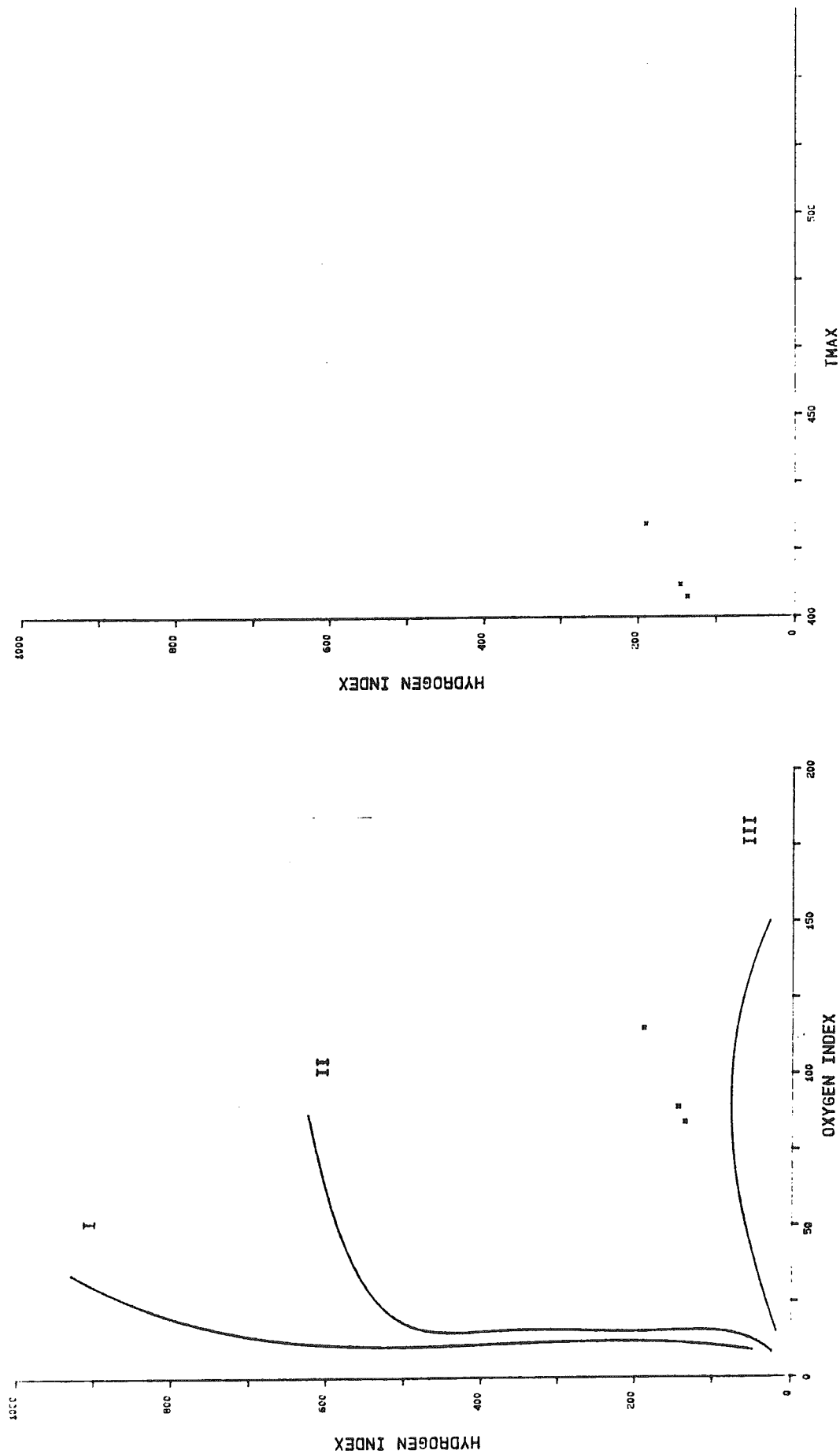


Figure 2u

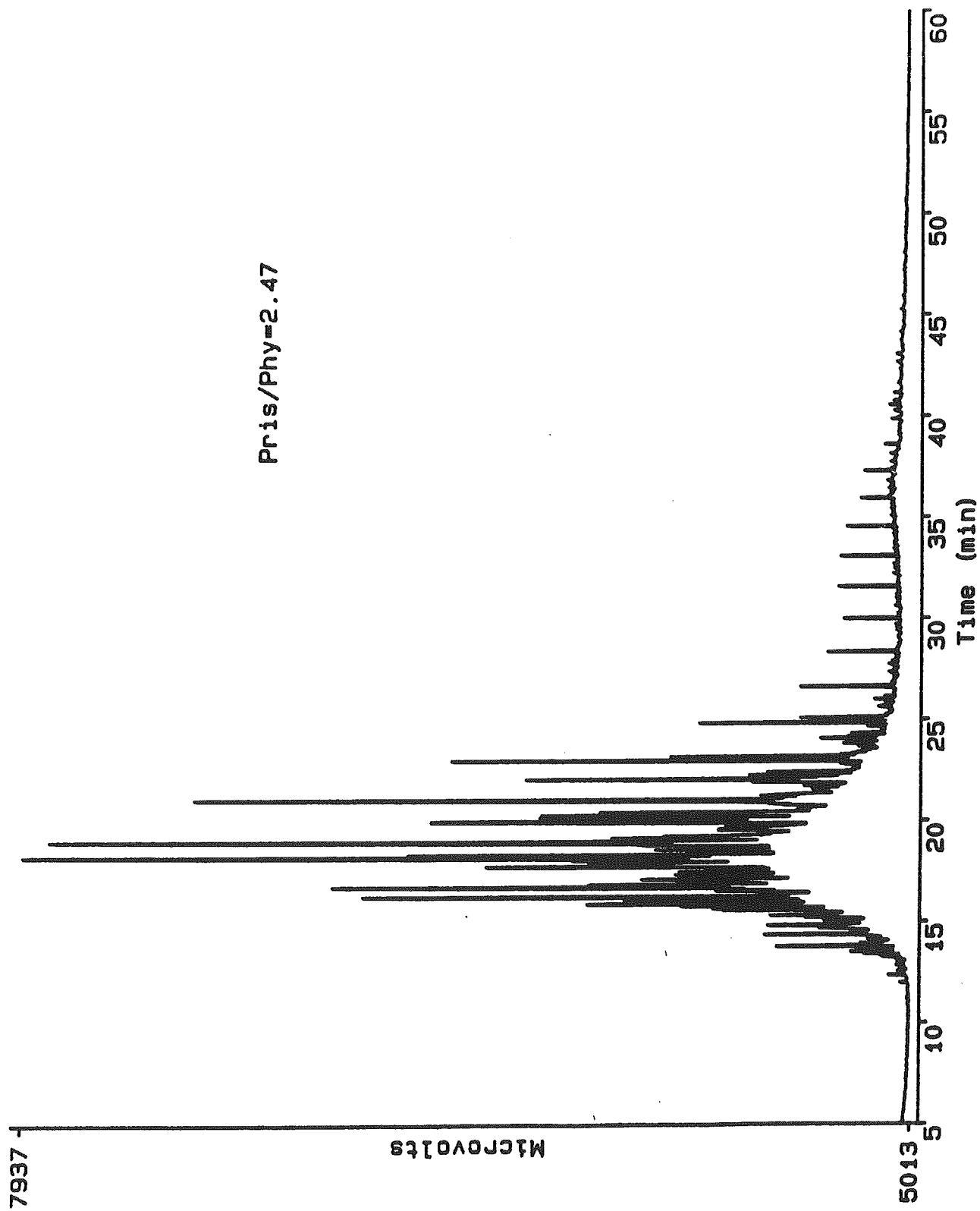


Figure 3a



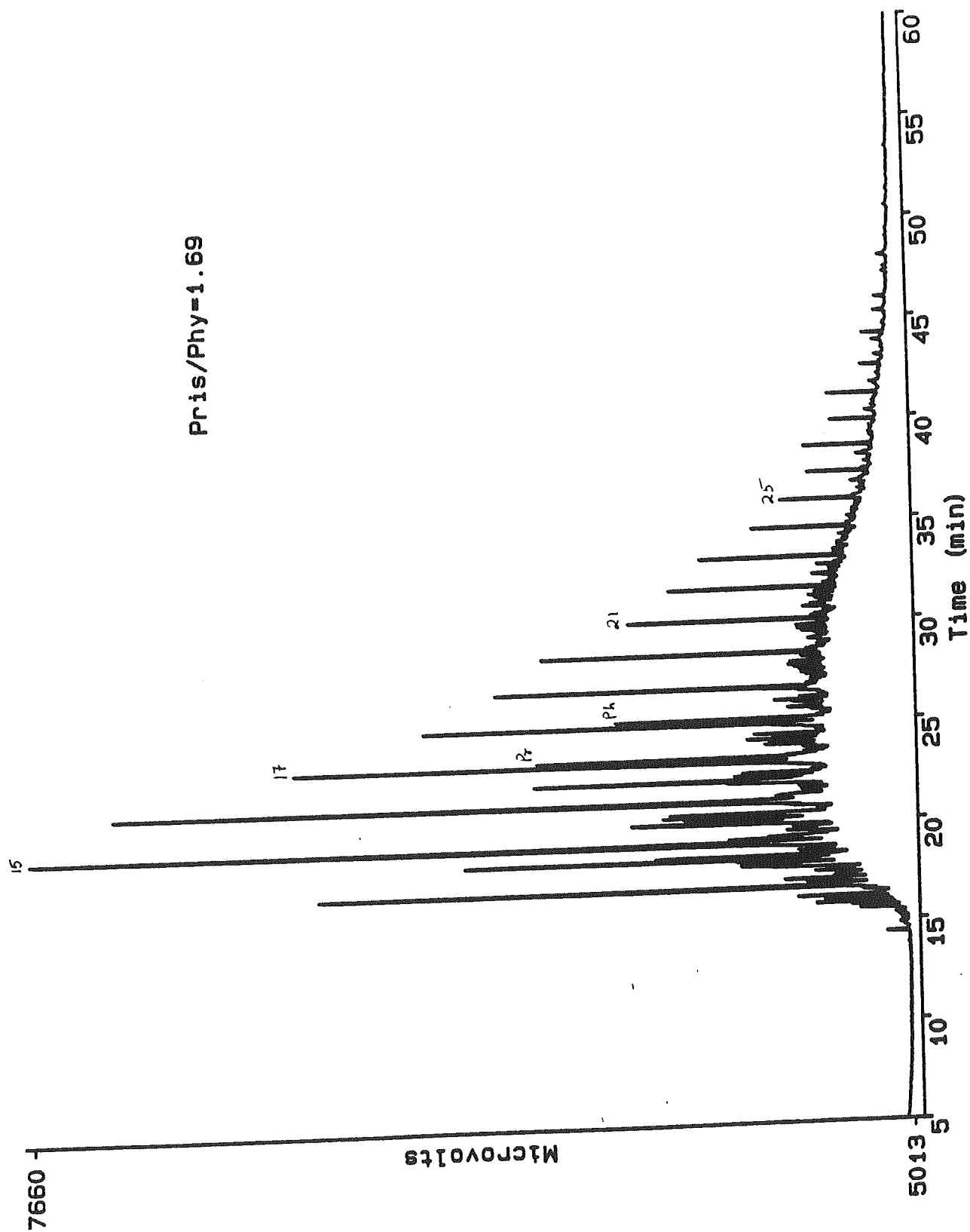


Figure 3b

#10549 CREE E-35 10960.

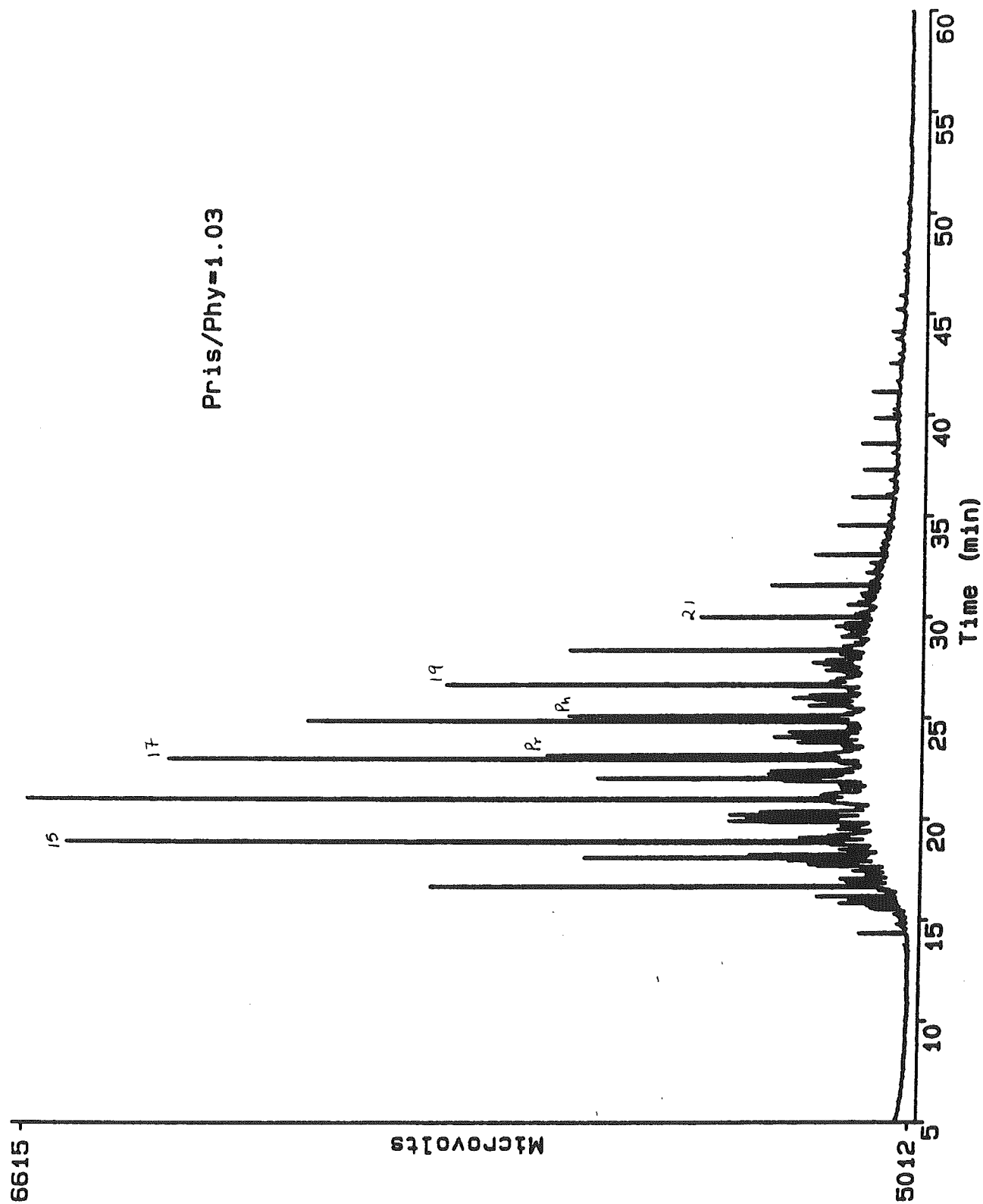
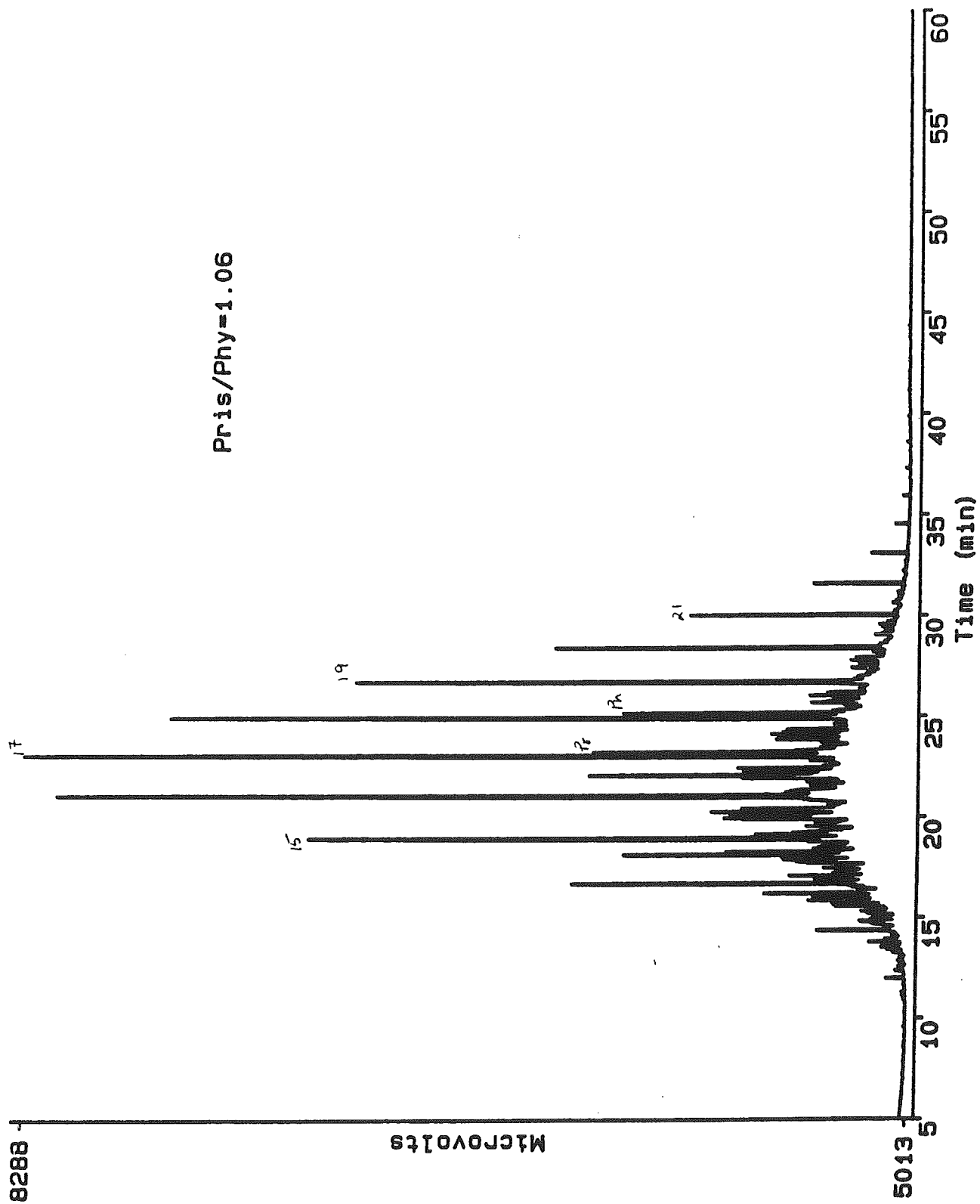


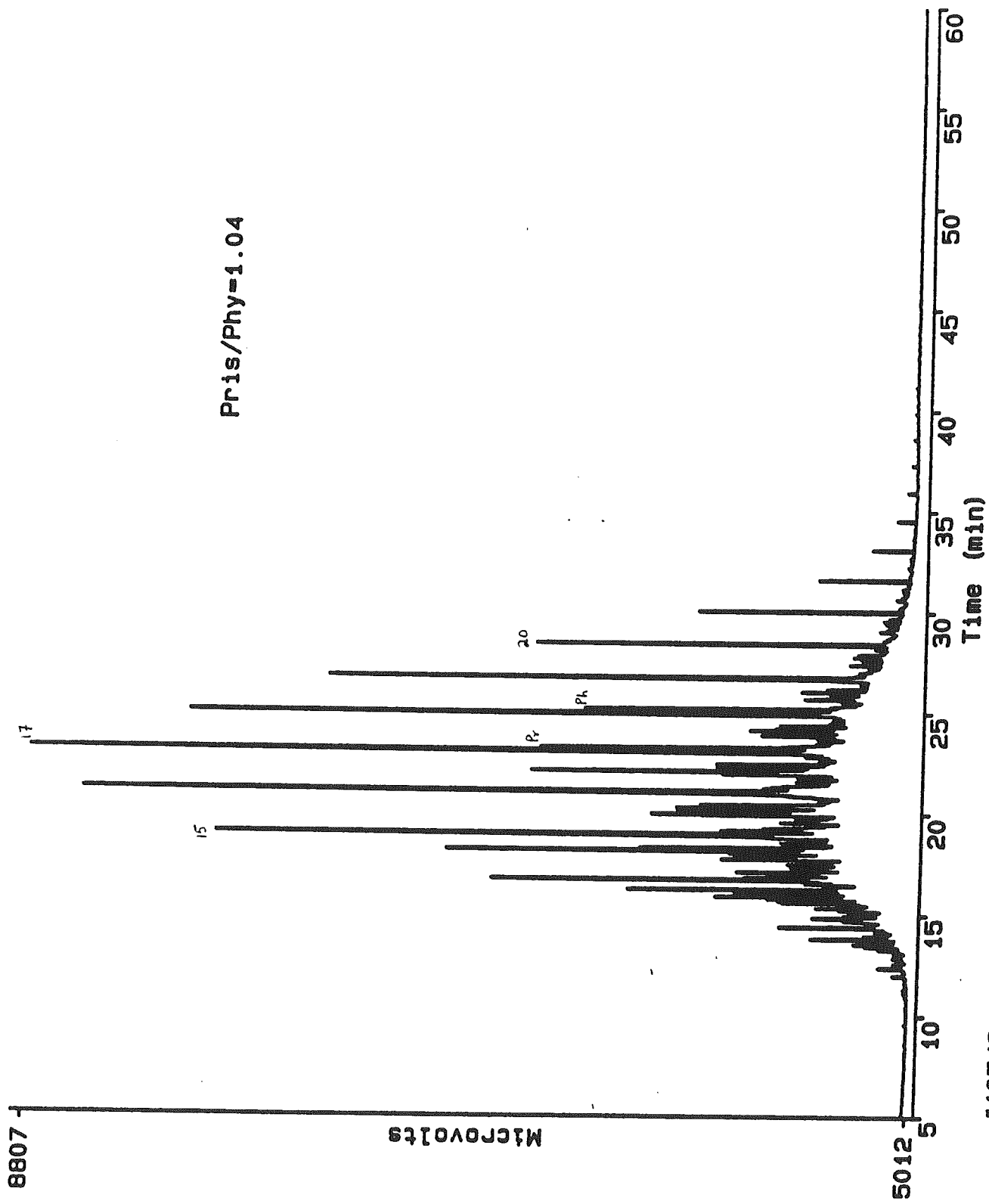
Figure 3c

#10550 MIGRANT N-20 11770°



#10544 N.TRIUMPH B-52 3660 m

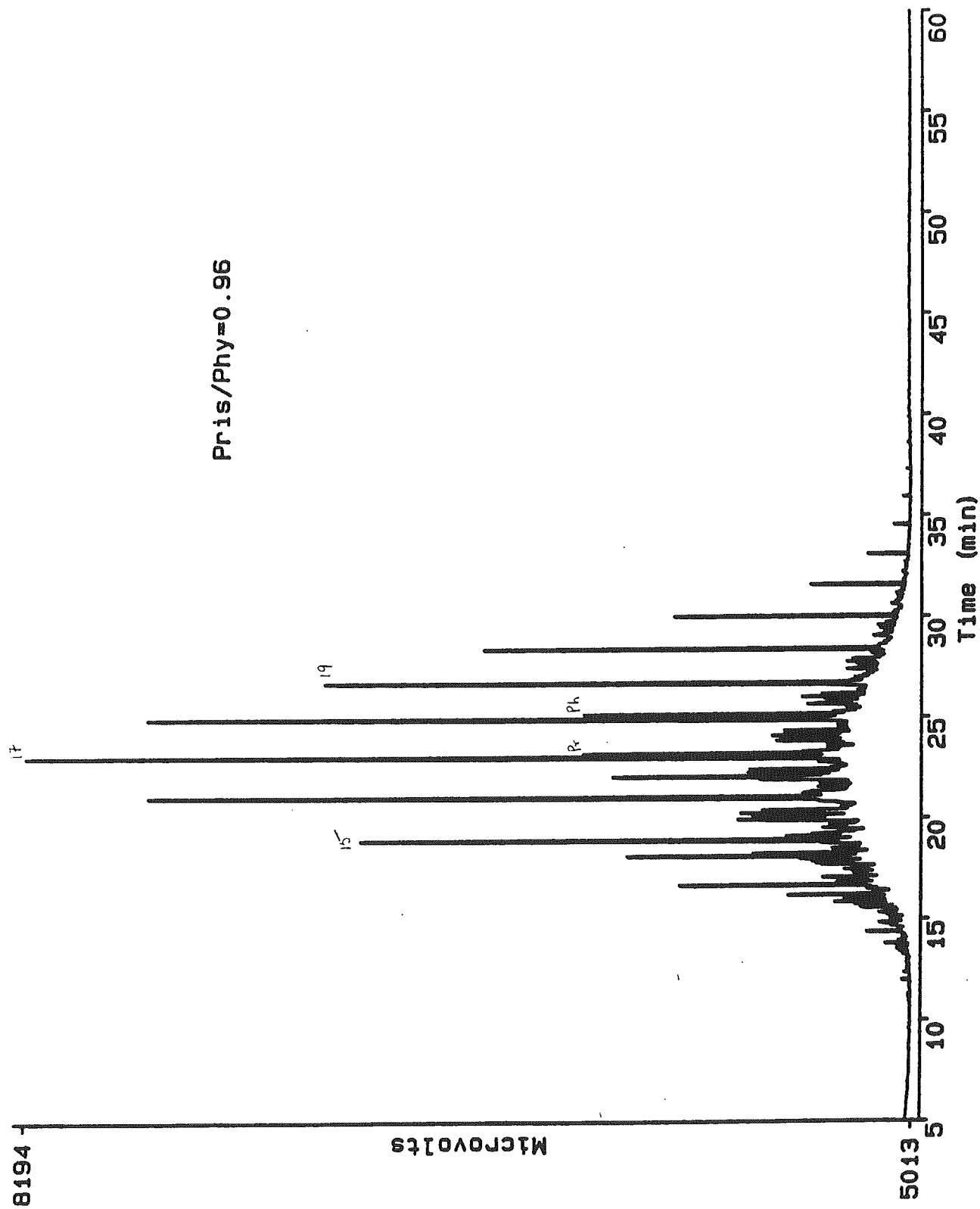
Figure 3d



Pris/Phy=1.04

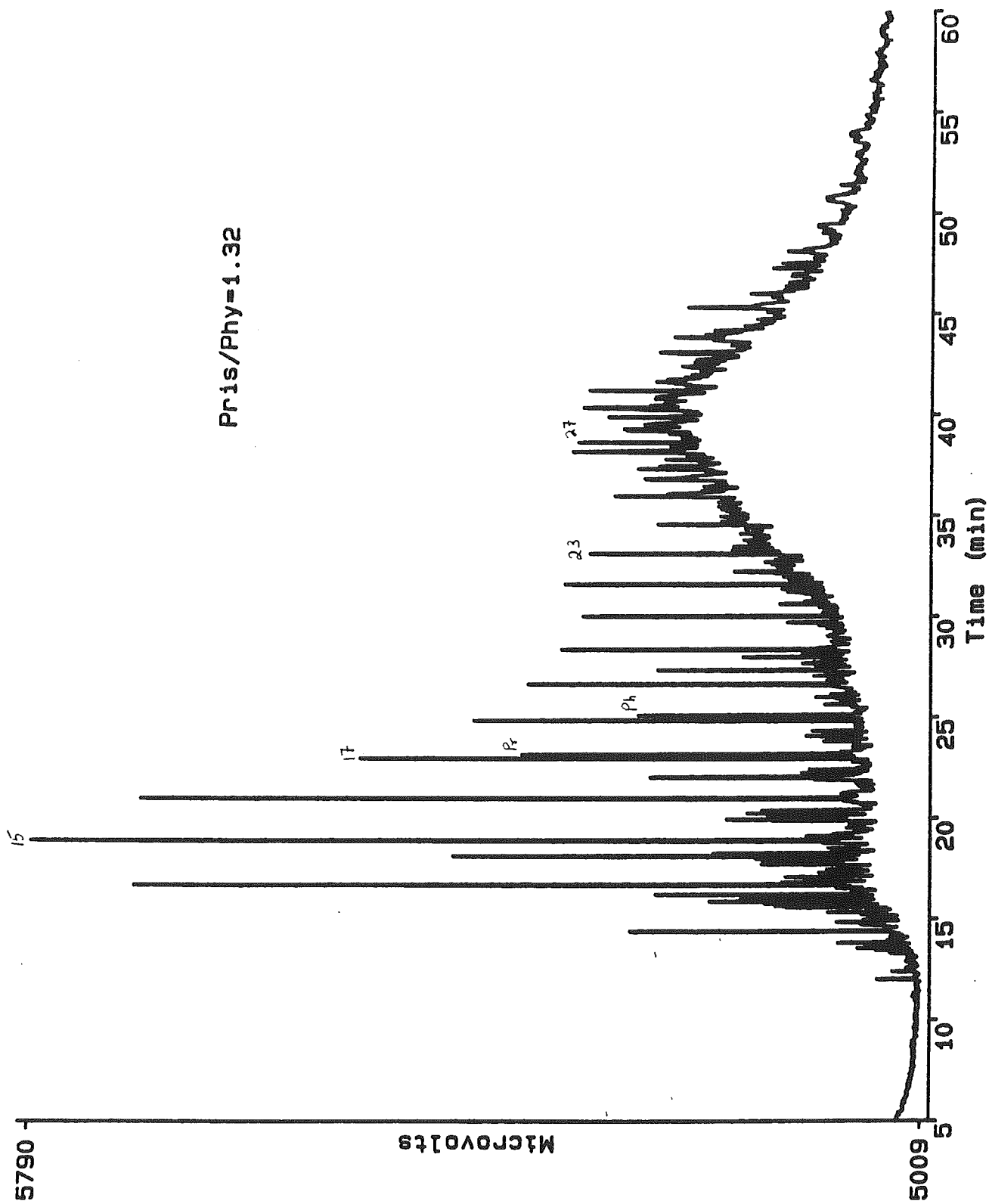
#10542 N.TRIUMPH G-43 3695 m

Figure 3e



#10543 N.TRIUMPH G-43 4845 m

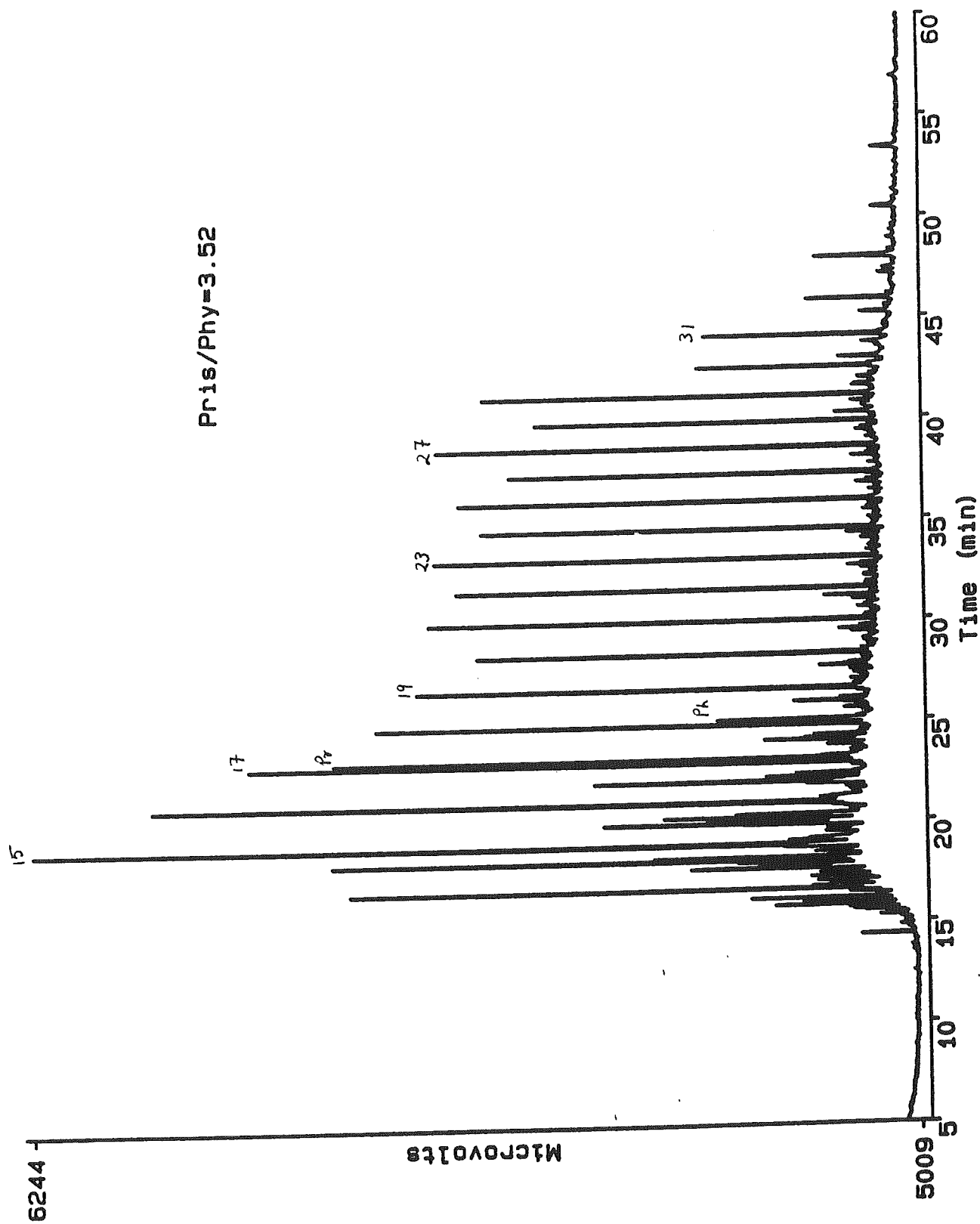
Figure 3f



Pris/Phy=1.32

#10541 PENEBCOT L-30 6950°

Figure 3g



#10552 S.DESBERRAS 0-76 3801 m

Figure 3h

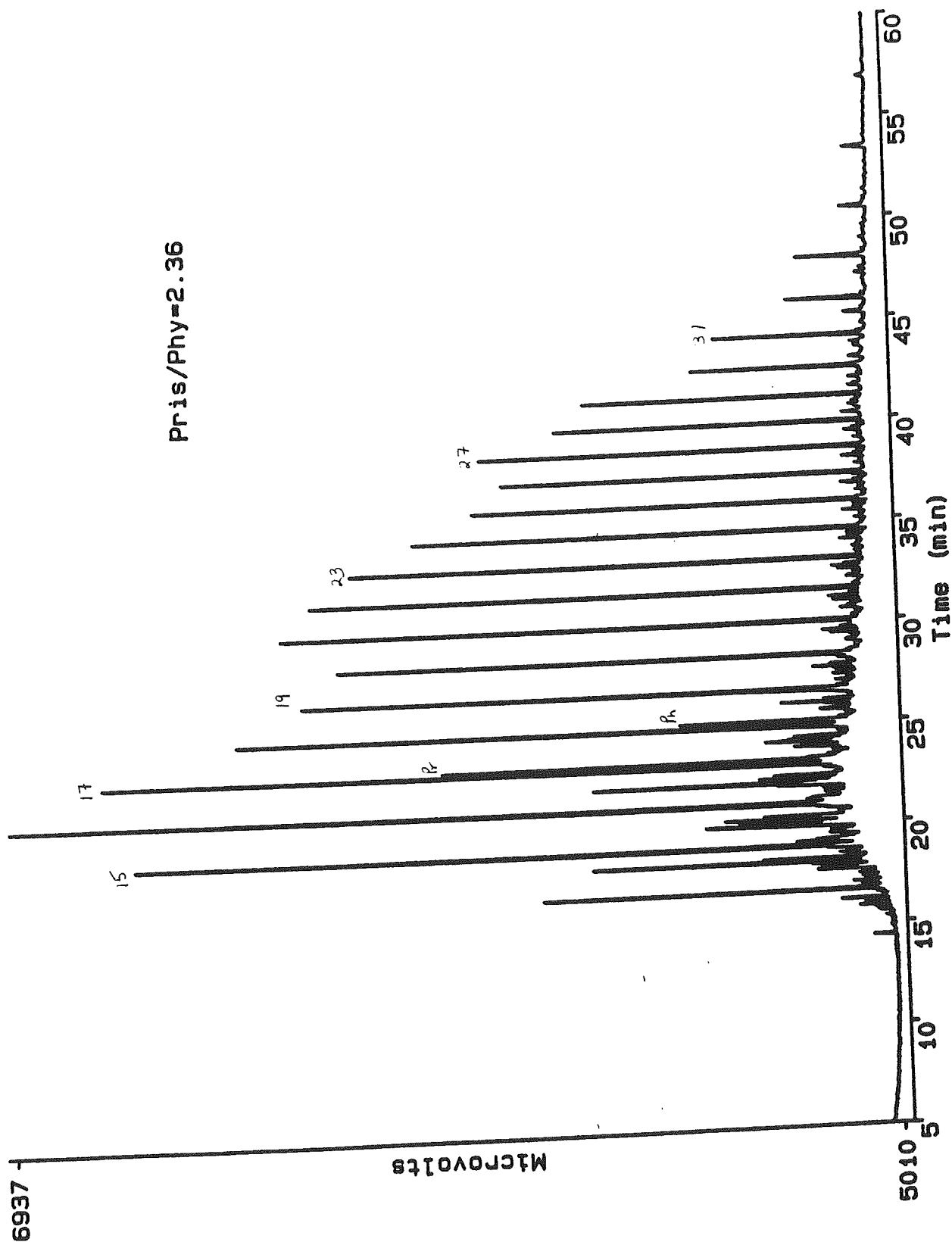


Figure 3i

#10547 SOUTH SABLE B-44 3938m



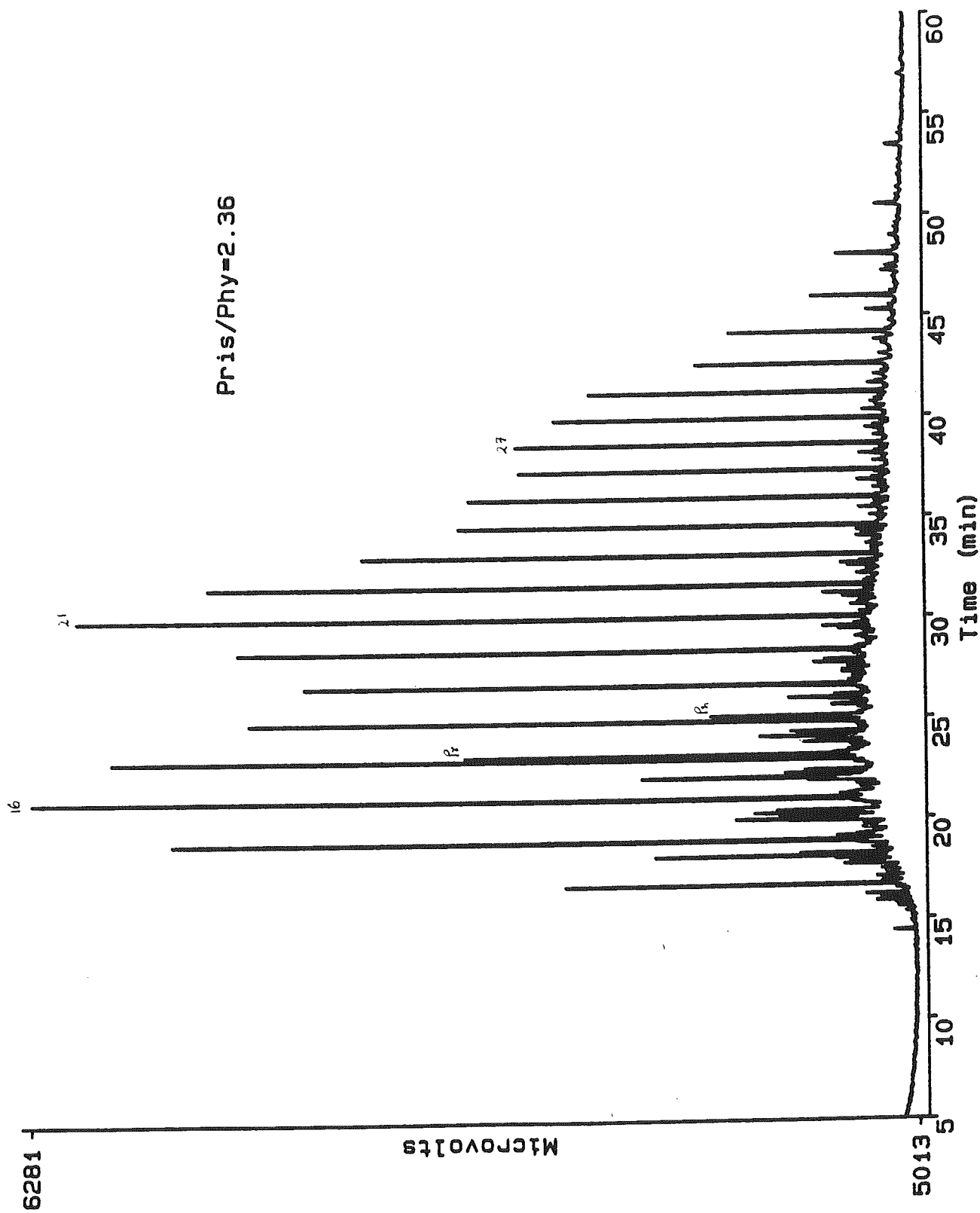
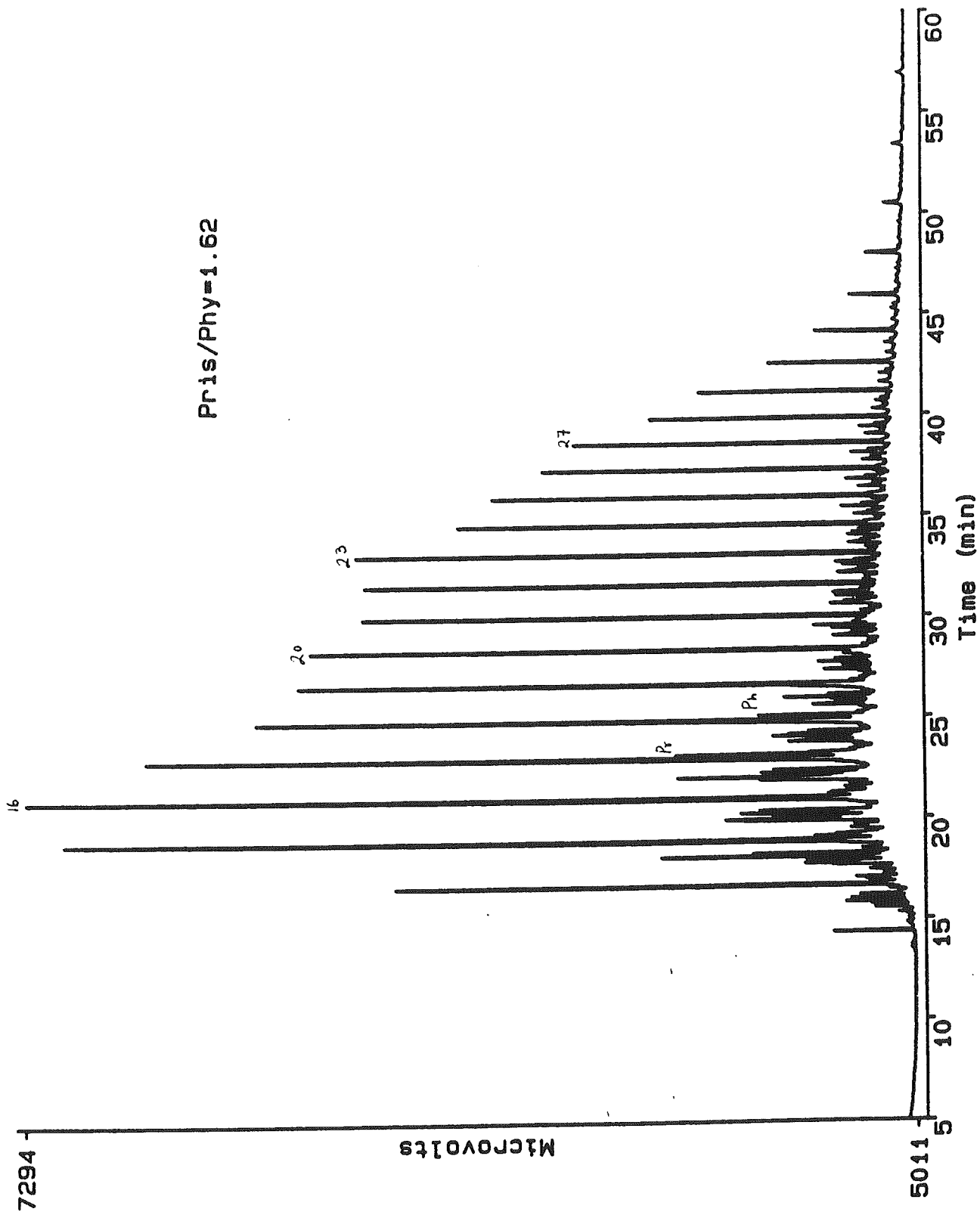


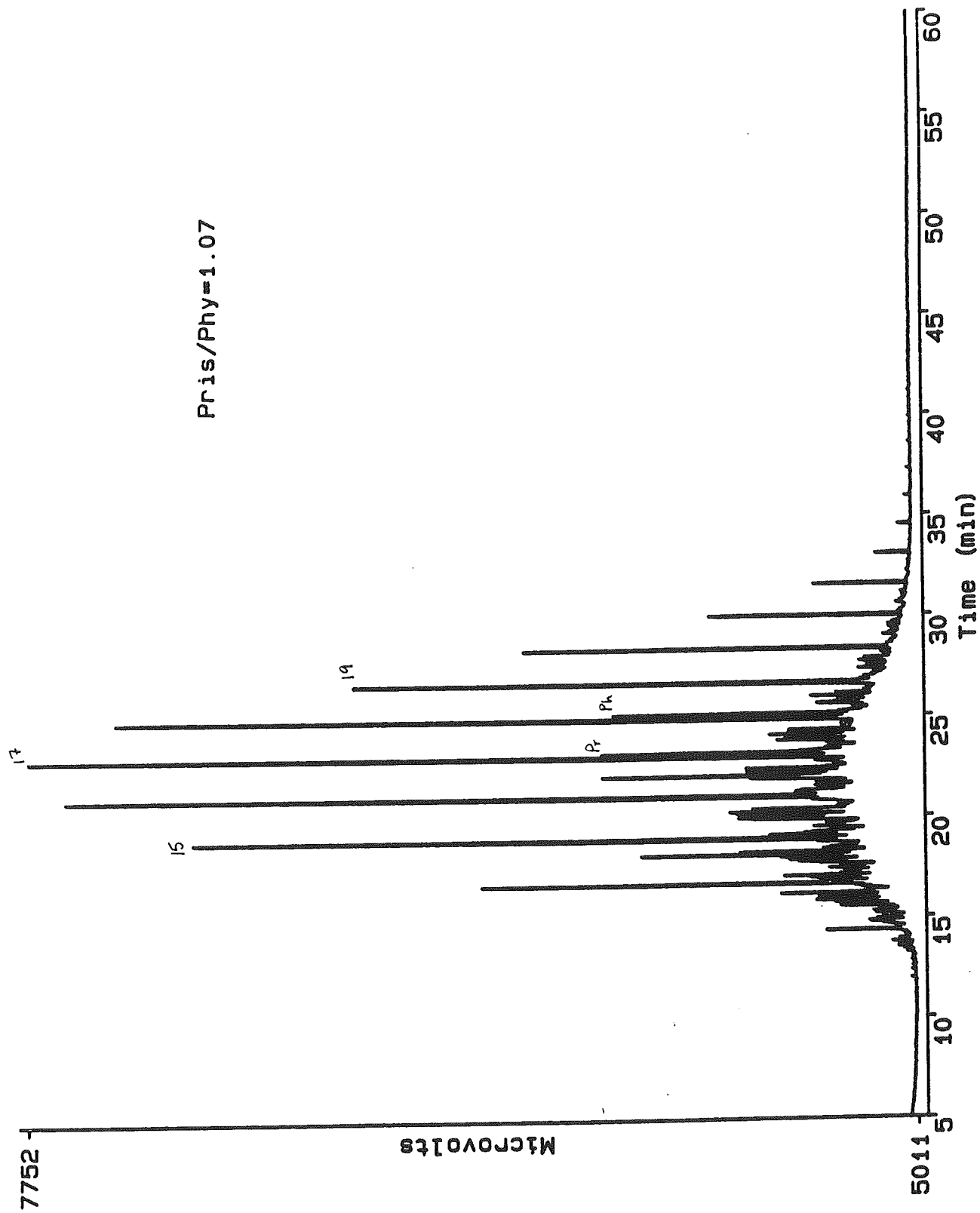
Figure 3j

#10545 THEBAUD C-74 3911 m



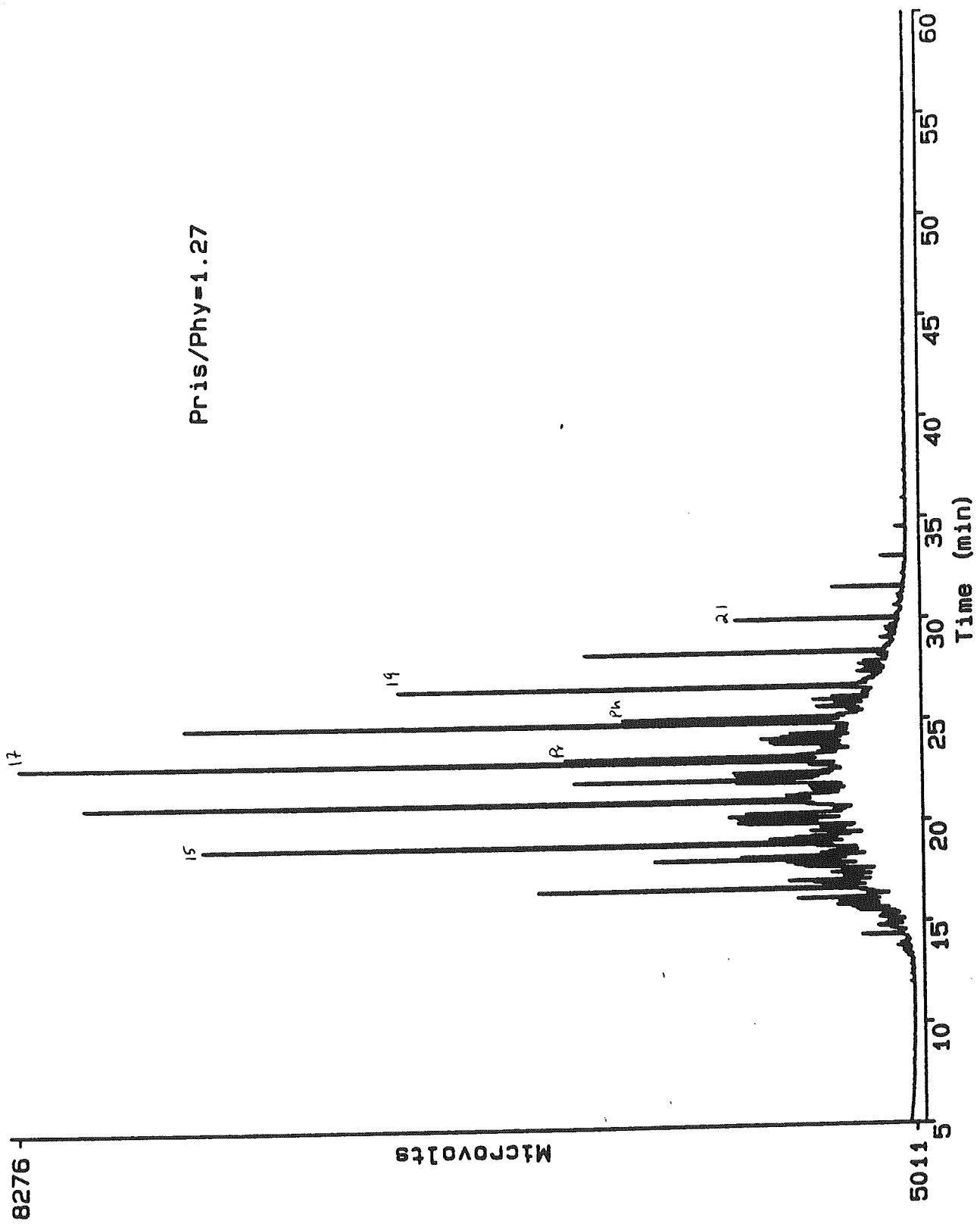
#10548 VENTURE B-52 5121 m

Figure 3k



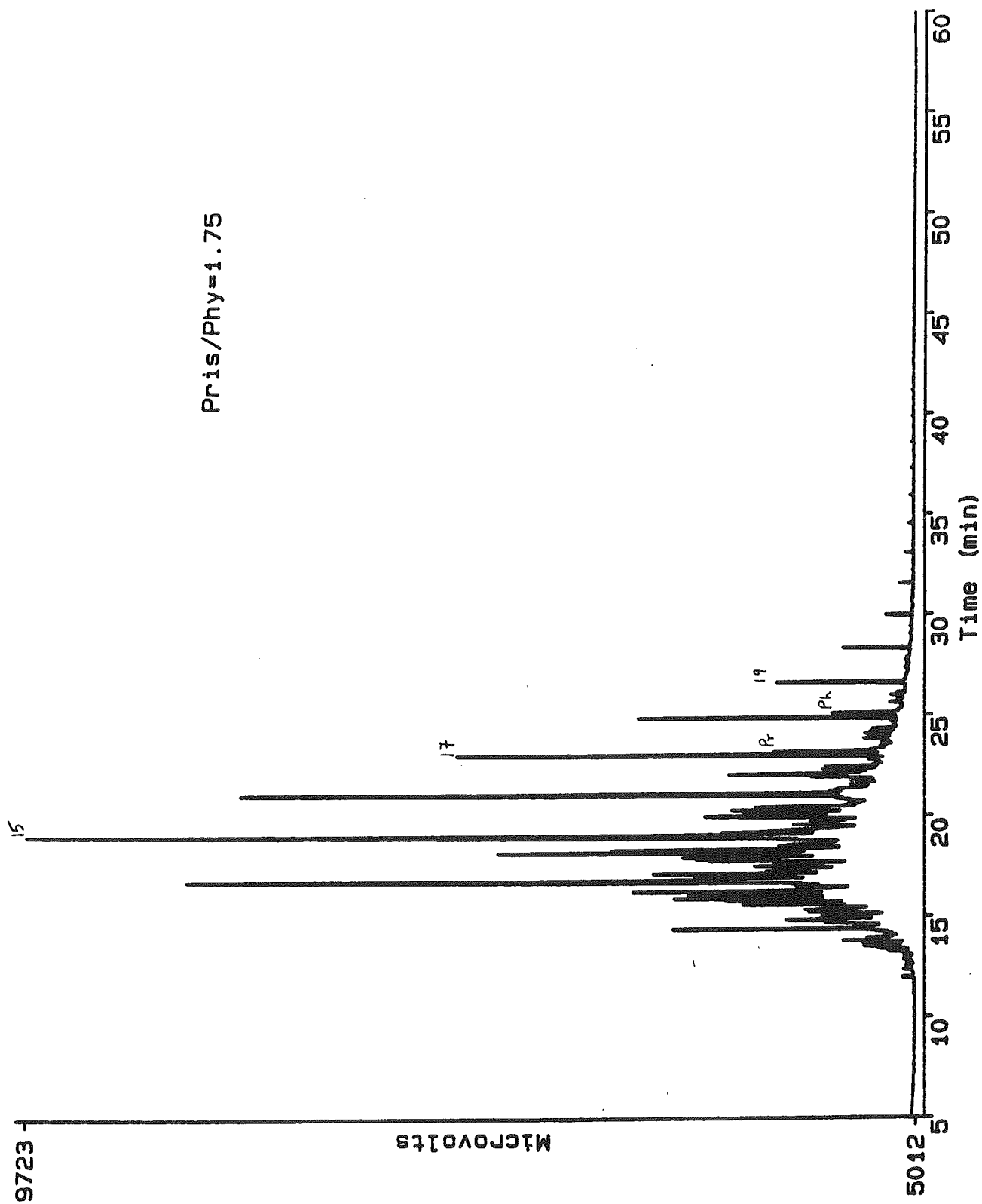
#10553 W.CHEBUCTO K-20 3345 m

Figure 31



#10554 W.CHEBUCTO K-20 5210 m

Figure 3m



Pris/Phy=1.75

#10551 WHYCOCOMAGH N-90 3310 m

Figure 3n

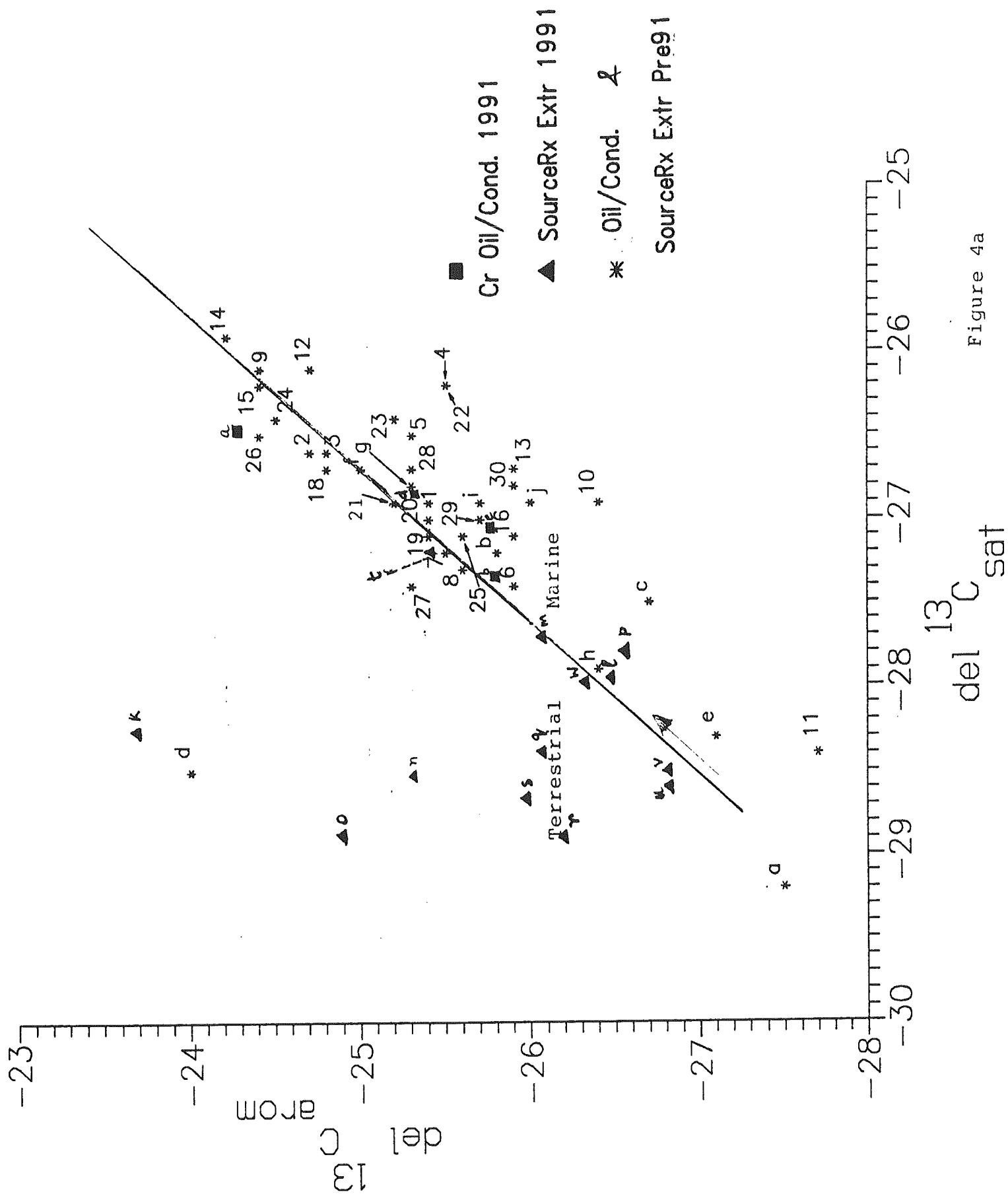


Figure 4a

Cr.Oil/Cond.1990 & earlier

1. Thebaud C-74, DST#9
2. Thebaud C-74, DST#4
3. Arcadia J-16, DST#9
4. Sable E-48, DST#16
5. Venture B-52, DST#13
6. Alma F-67, DST#2
7. Panuke B-90, DST#1
8. S. Venture O-59, DST#10
9. Chebuctok-90, DST#4
10. PrimroseA-41, DST#2
11. CohassetA-52, DST#5
12. PrimroseN-50, DST#1
13. Citnaltai-59, DST#3
14. Glenelg J-48, DST#9
15. Glenelg J-48, DST#8
16. Venture B-13, DST#11
18. N. Truimph B-52, DST#4
19. CohassetA-52, DST#2
20. CohassetD-42, PT#3
21. Alma F-67, DST#7
22. Sable 3H-58, DST#4
23. Banquereau C-21, DST#2
24. Venture B-43, DST#2
25. Olympia A-12, DST#5

Cr.Oil/Cond.1991

- b. Bluenose 2G-47 DST #8
- c. Penobscot L-30 RFT #5
- d. Venture H-22 DST #5

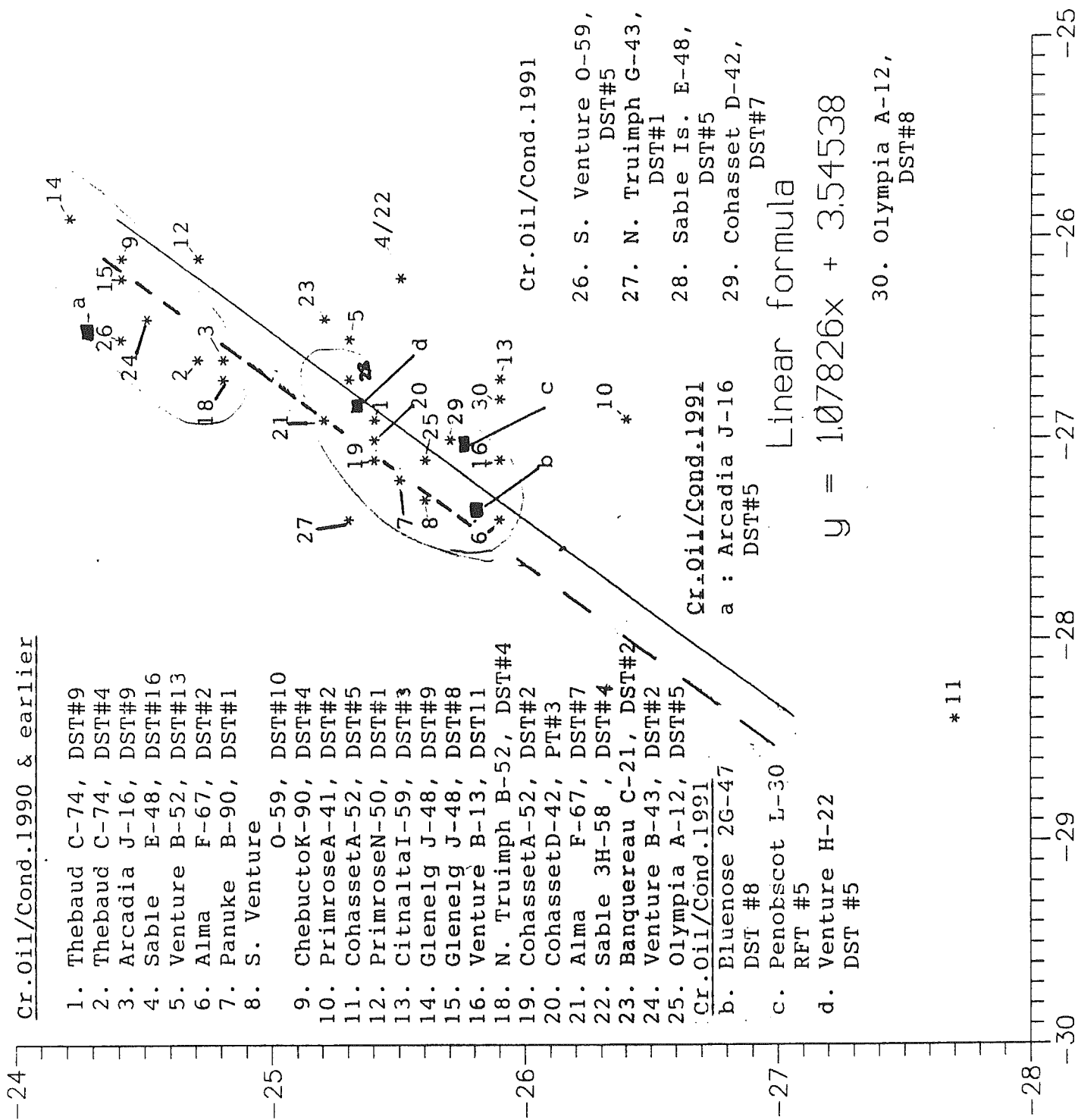
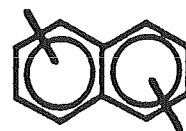
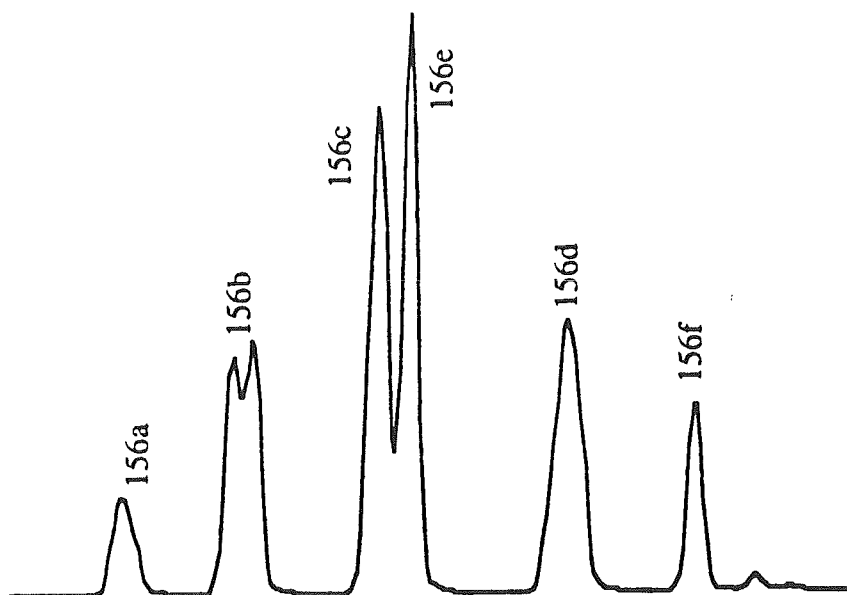


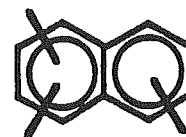
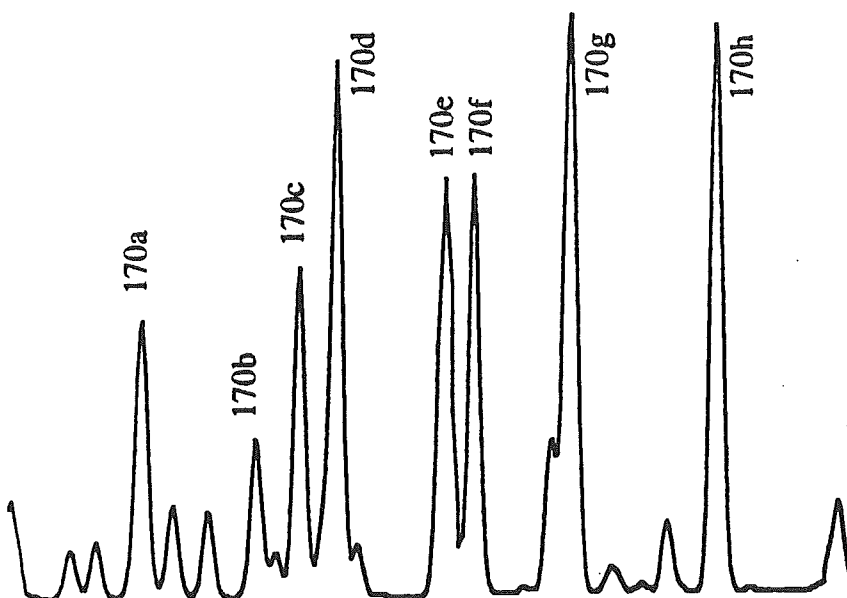
Figure 4b



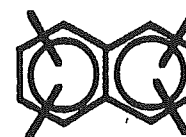
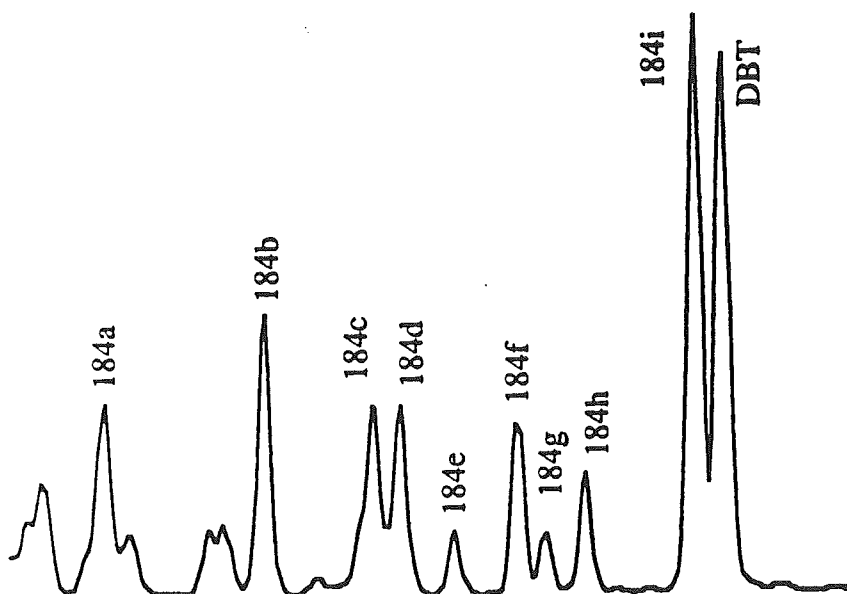




**M/Z 156**  
**C2-ALKYLNAPHTHALENES**



**M/Z 170**  
**C3-ALKYLNAPHTHALENES**



**M/Z 184**  
**C4-ALKYLNAPHTHALENES**  
**and DIBENZOTHIOPHENE**

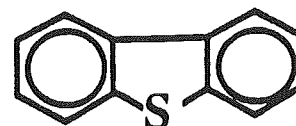
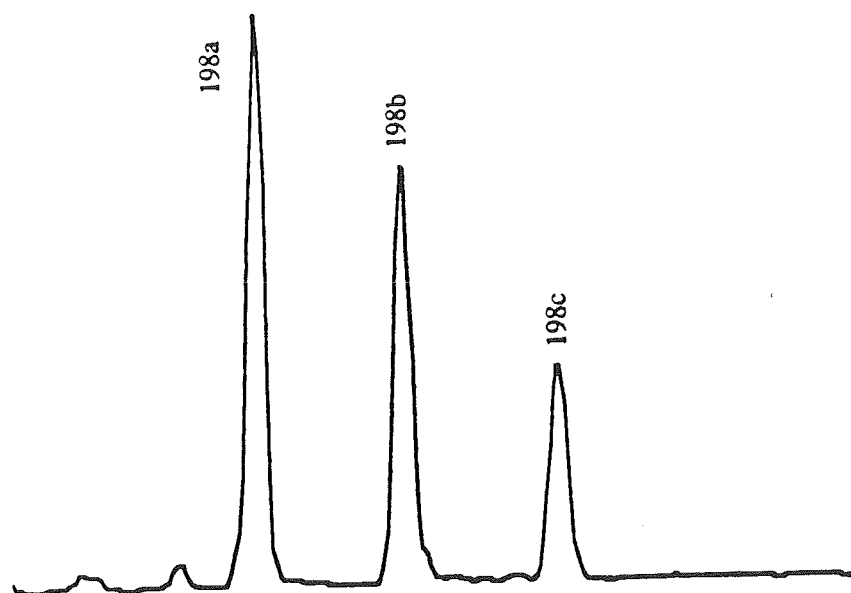
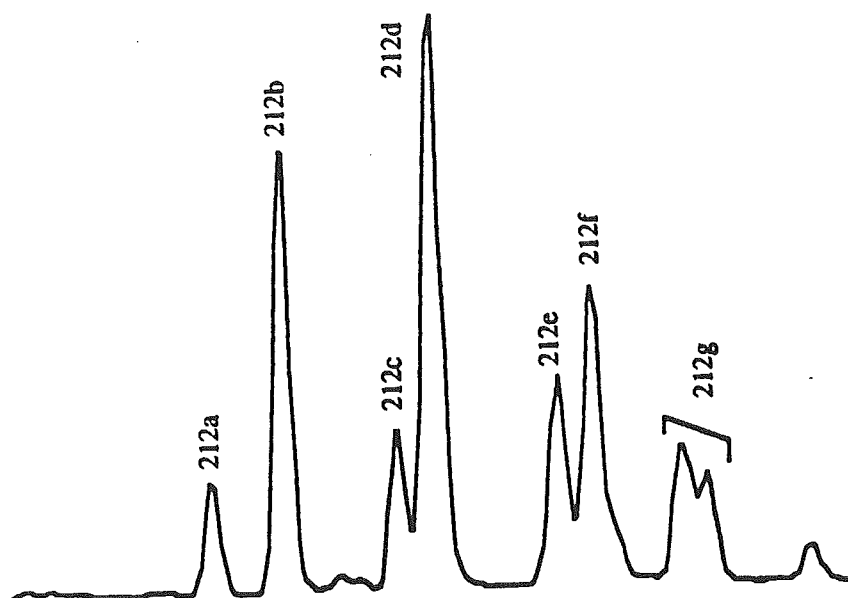
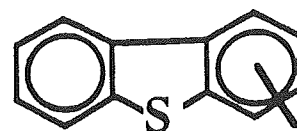


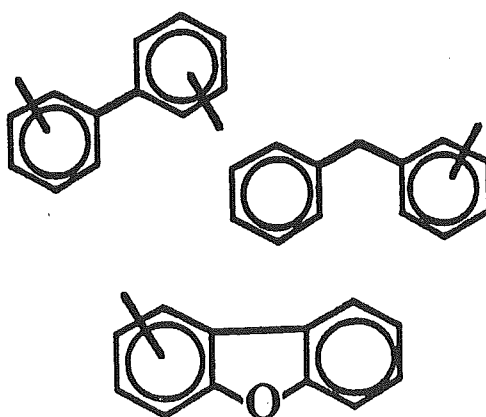
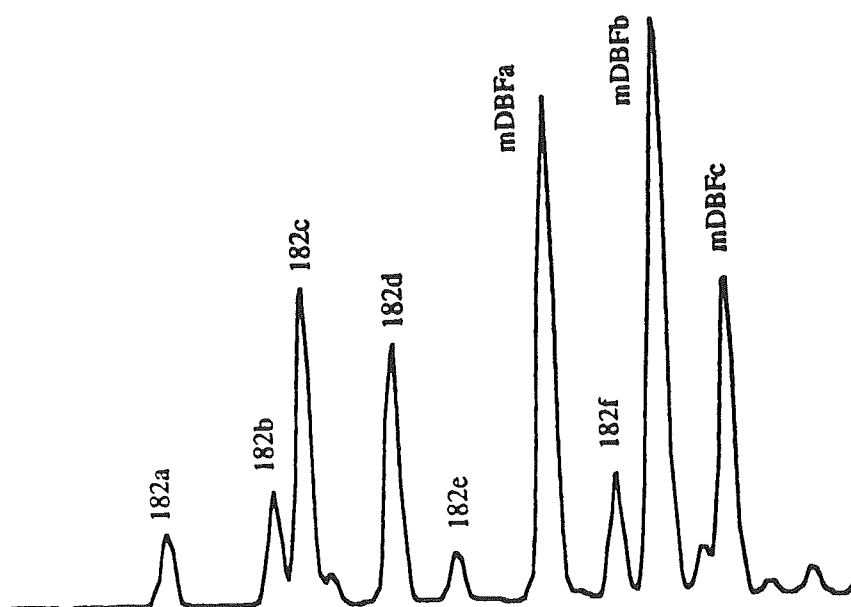
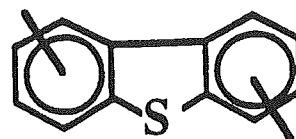
Figure 6— Mass chromatograms of the isomers of naphthalene homologues (Sample NS9101). Peaks used in the study are labelled and molecular structures are shown.



**M/Z 198**  
**METHYLDIBENZOTHIOPHENES**



**M/Z 212**  
**DIMETHYLDIBENZOTHIOPHENES**



**M/Z 182**  
**DIMETHYLBIPHENYLS**  
**METHYLDIPHENYLMETHANE**  
**METHYLDIBENZOFURANS**

Figure 7 — Partial m/z 198, 212 and 182 mass chromatograms (Sample NS9101). Peaks used in the study are labelled and molecular structures are shown.

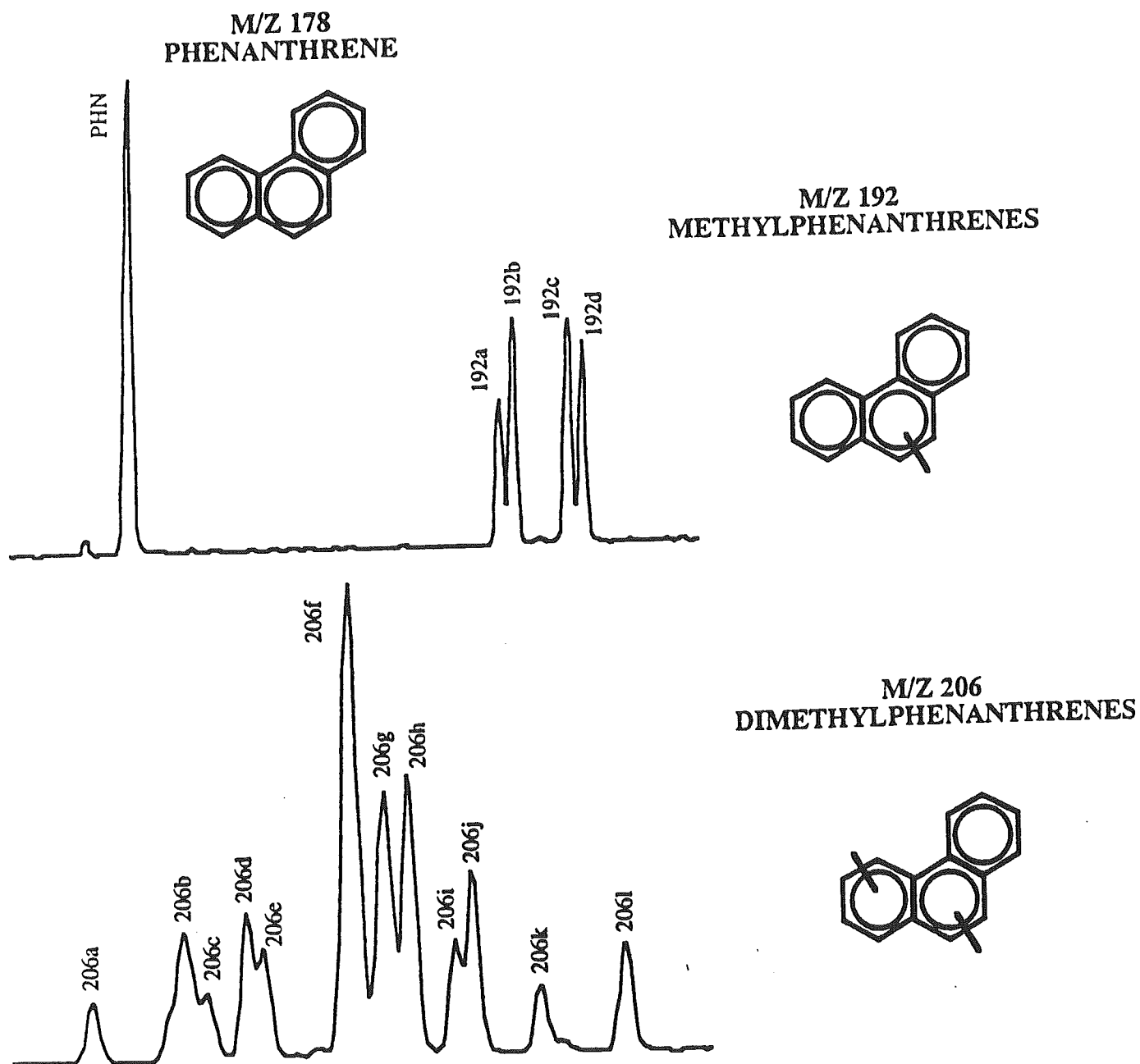
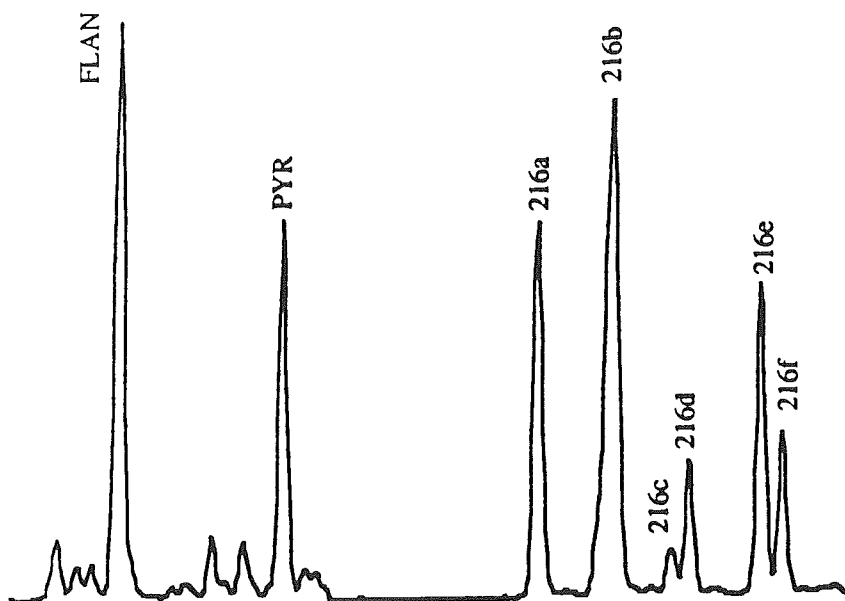
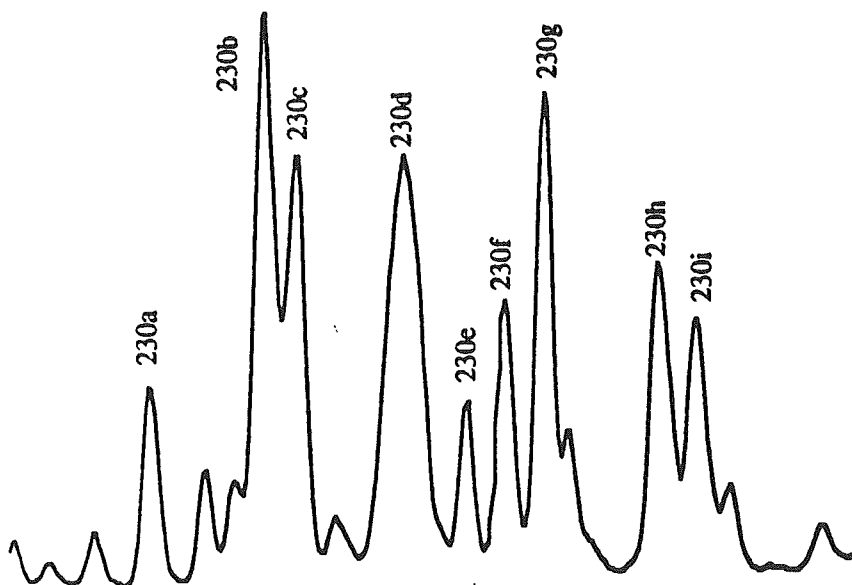
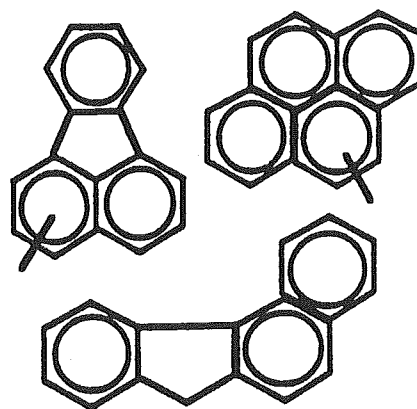


Figure 8 — Partial m/z 178, 192 and 206 mass chromatograms of sample NS9101. 178 and 192 are combined. Peaks are labelled and molecular structures are shown.

**M/Z 202  
PYRENE  
FLUORANTHENE**



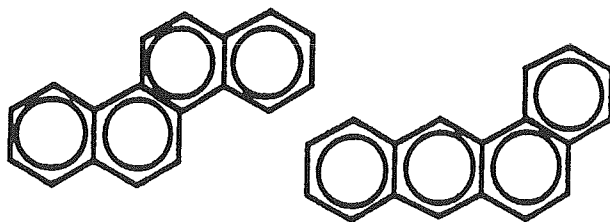
**M/Z 216  
METHYLPYRENES  
METHYLFLUORANTHENES  
BENZOFLUORENE**



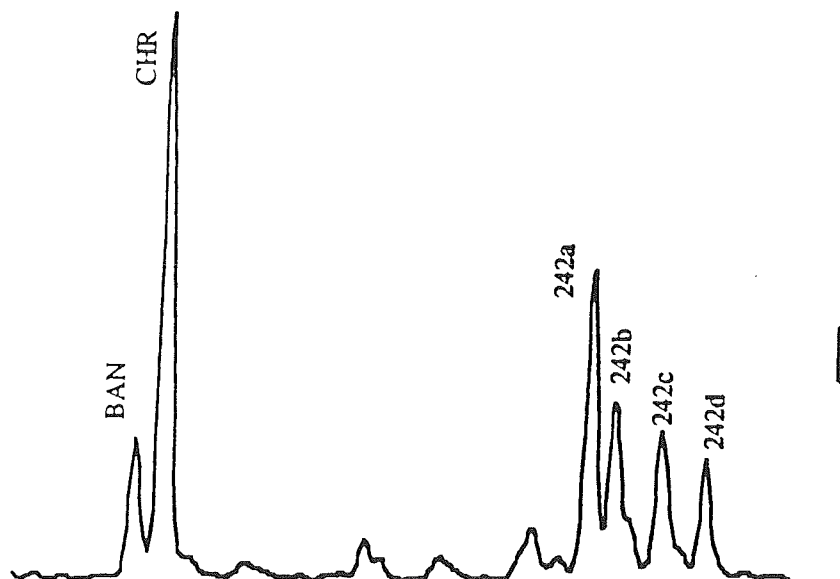
**M/Z 230  
DIMETHYLPYRENES  
DIMETHYLFLUORANTHENES  
METHYLBENZOFLUORENES**

Figure 9 — Partial m/z 202, 216 and 230 mass chromatograms of sample NS9101. 202 and 216 are combined. Peaks are labelled and examples of molecular structures are shown.

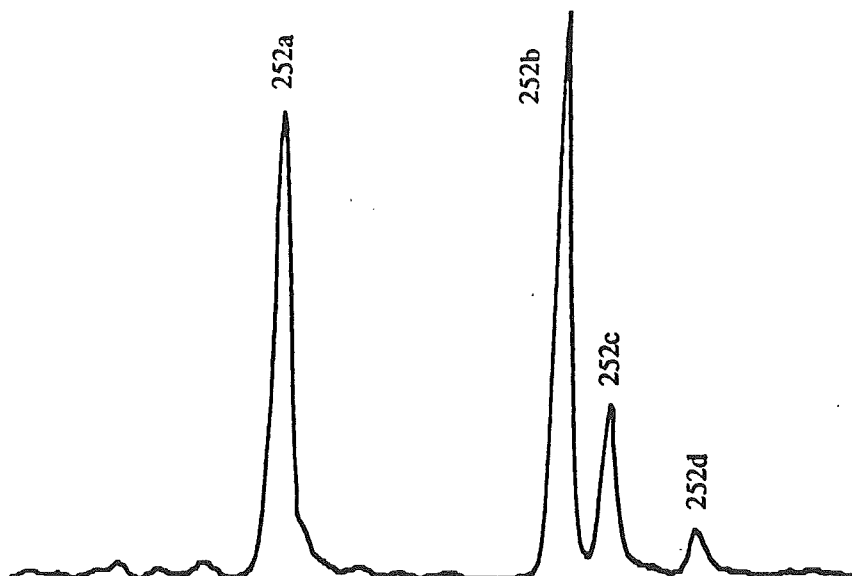
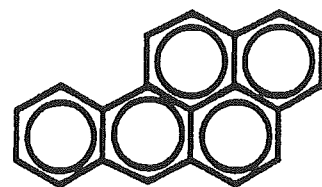
M/Z 228  
CHRYSENE  
BENZO[a]ANTHRACENE



M/Z 242  
METHYLCHRYSENES & ISOMERS



M/Z 252  
BENZO[a]PYRENE & ISOMERS



M/Z 231  
TRIAROMATIC STEROIDS

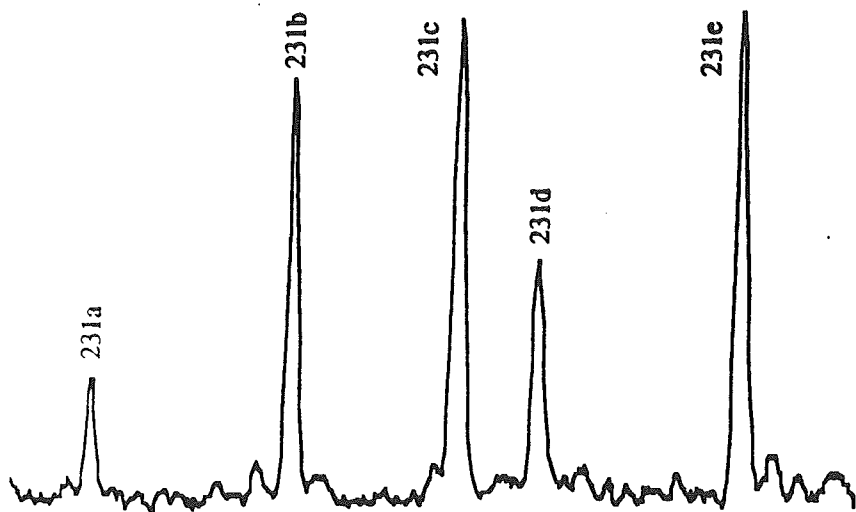
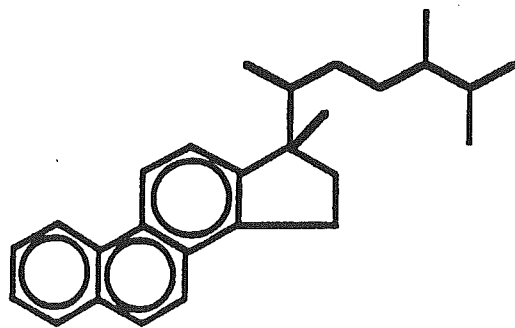


Figure 10— Partial m/z 228, 242, 252 and 231 mass chromatograms of sample NS9101. 228 and 242 are combined. Peaks are labelled and examples of molecular structures are shown.

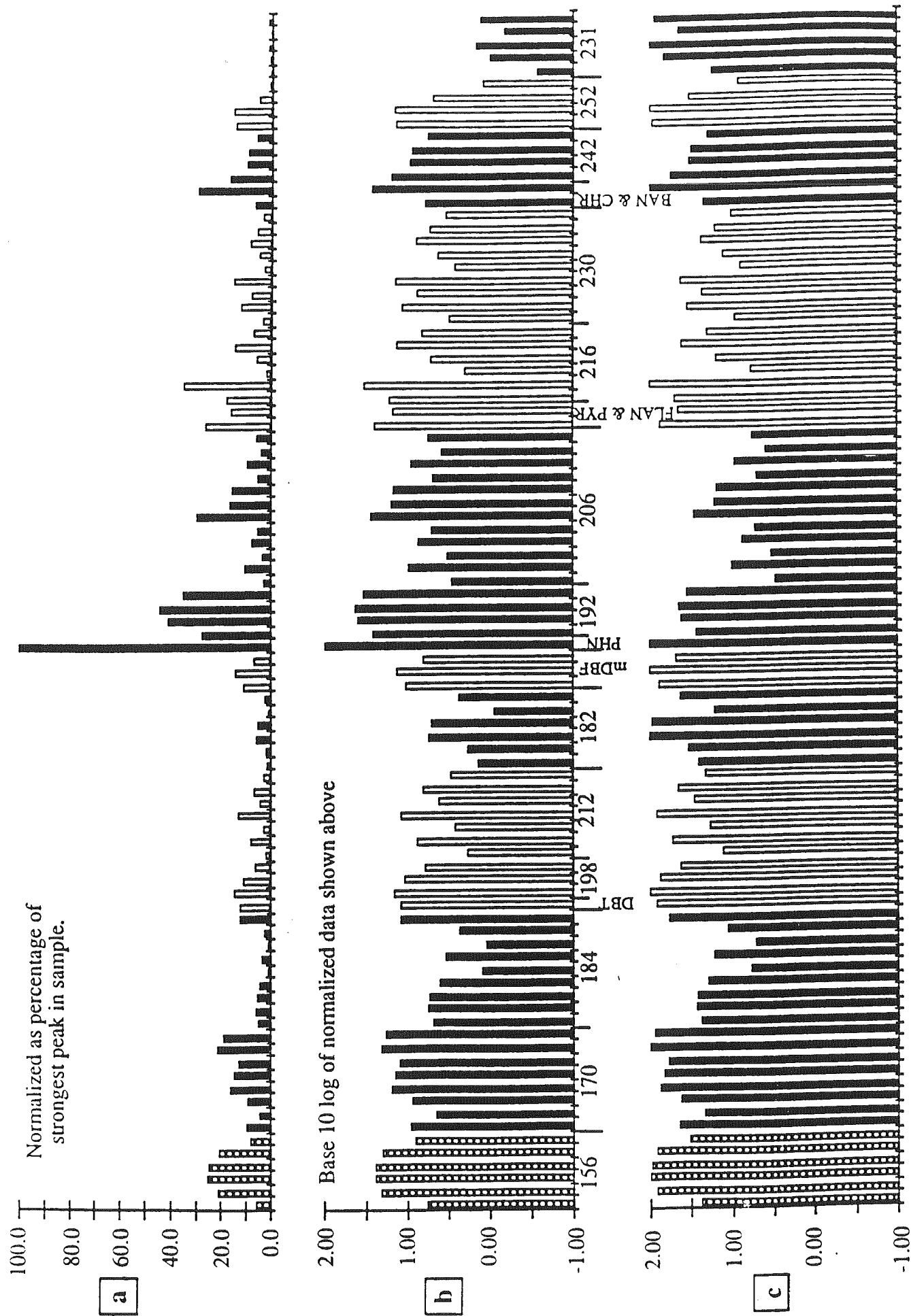
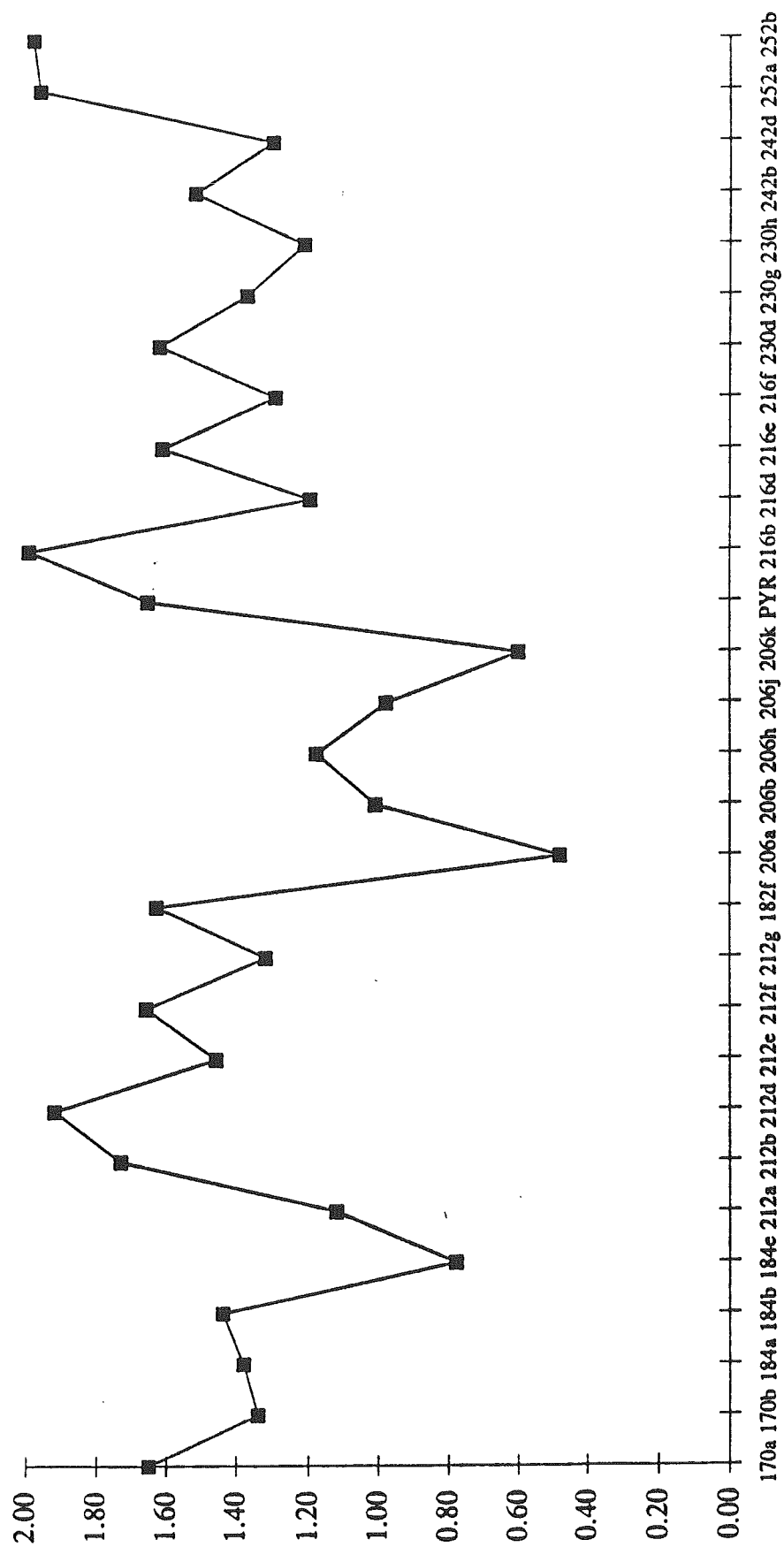


Figure 1 1— Three alternate representations of the integrated peak area data for sample NS9101 (See text).

Figure 12— Correlation subset of the 29 maturation-insensitive peaks for sample NS9101 (see text).



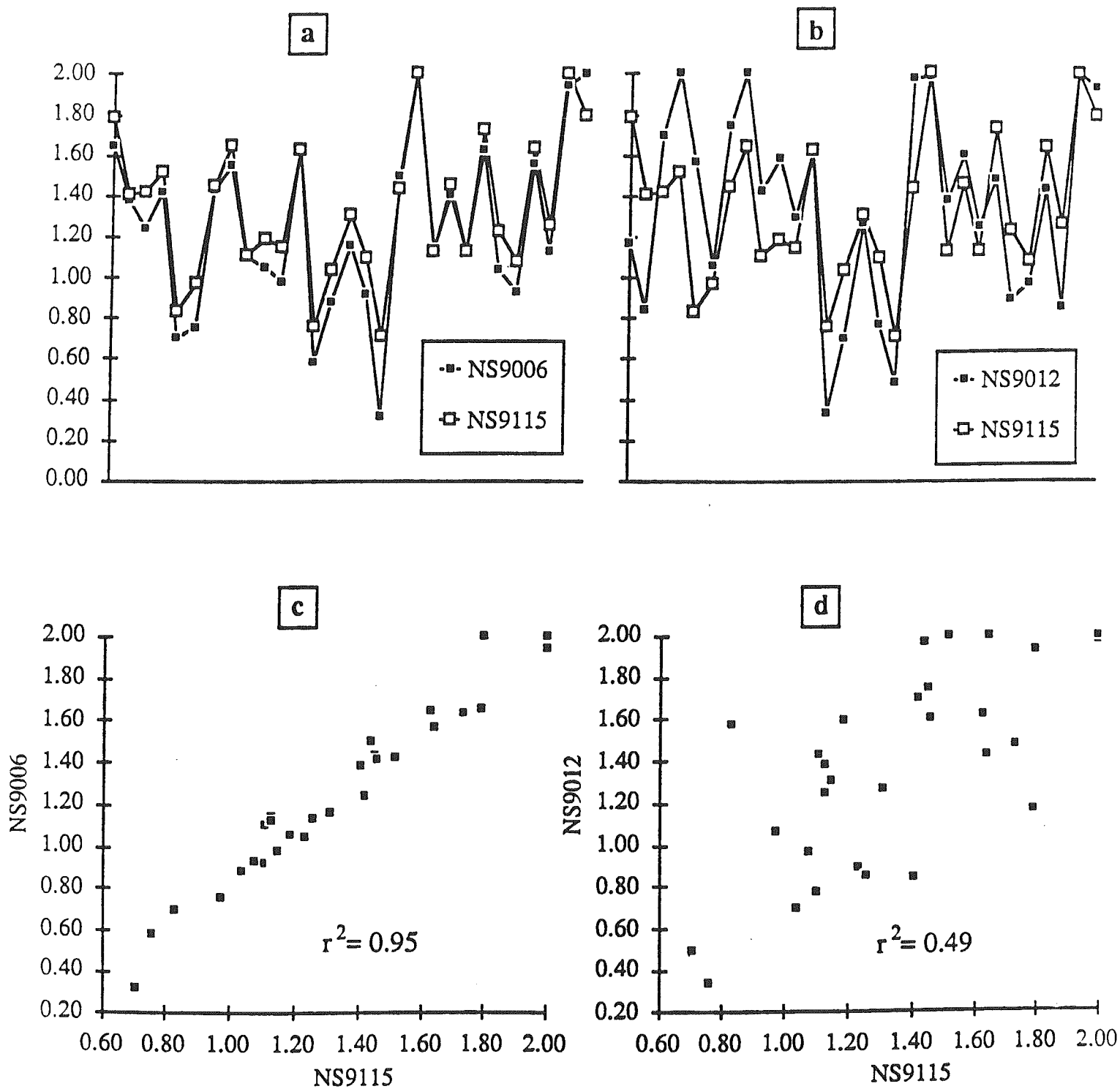


Figure 13— Examples of co-plotted (9a, 9b) and cross-plotted (9c, 9d) aromatic correlation data.



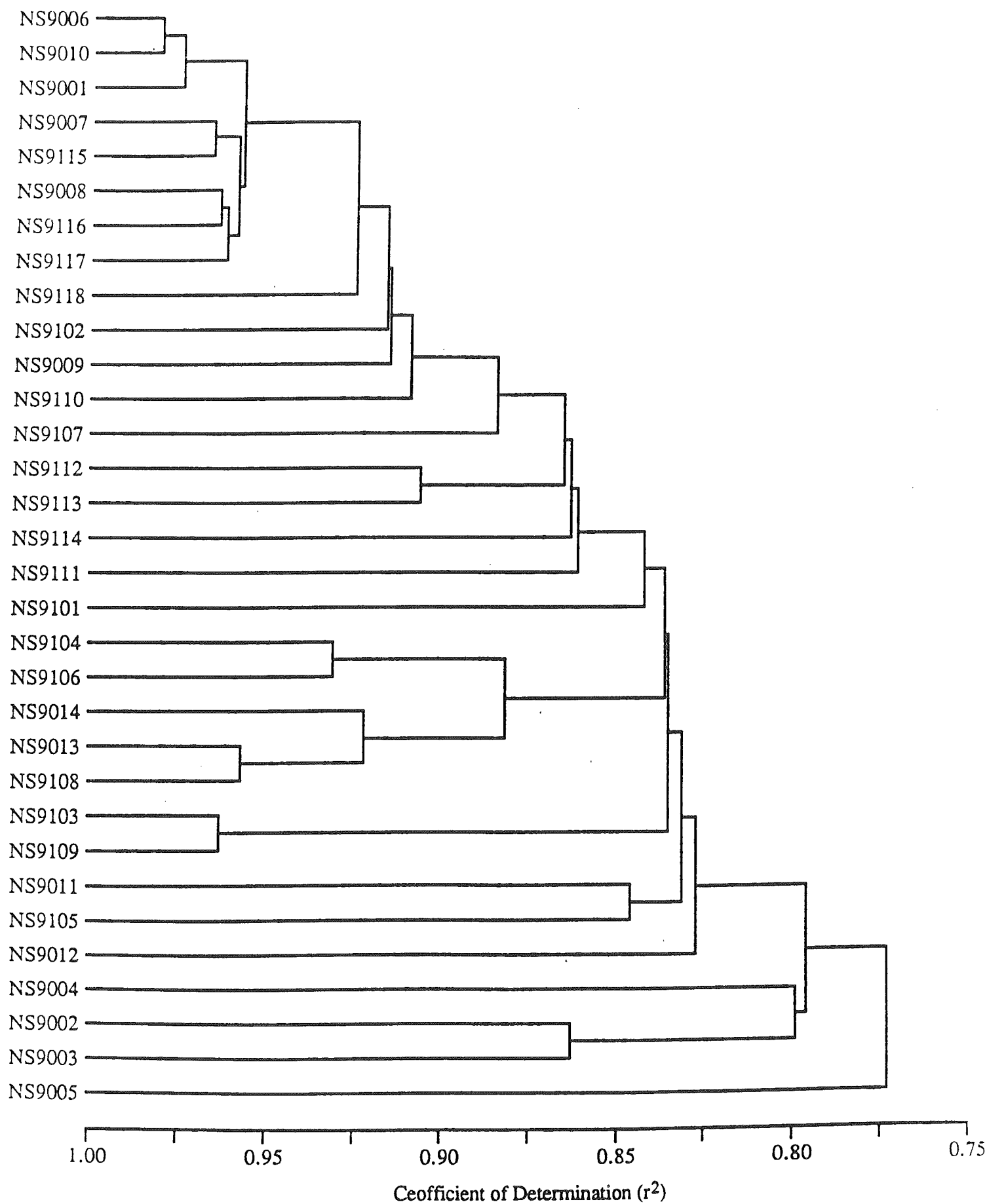


Figure 14 — Dendrogram of Scotian Shelf oils and rock extracts formed by the single linkage method (Massart and Kaufman, 1983), using coefficients of determination from the multiple linear regression of 29 maturation insensitive polyaromatic compounds.

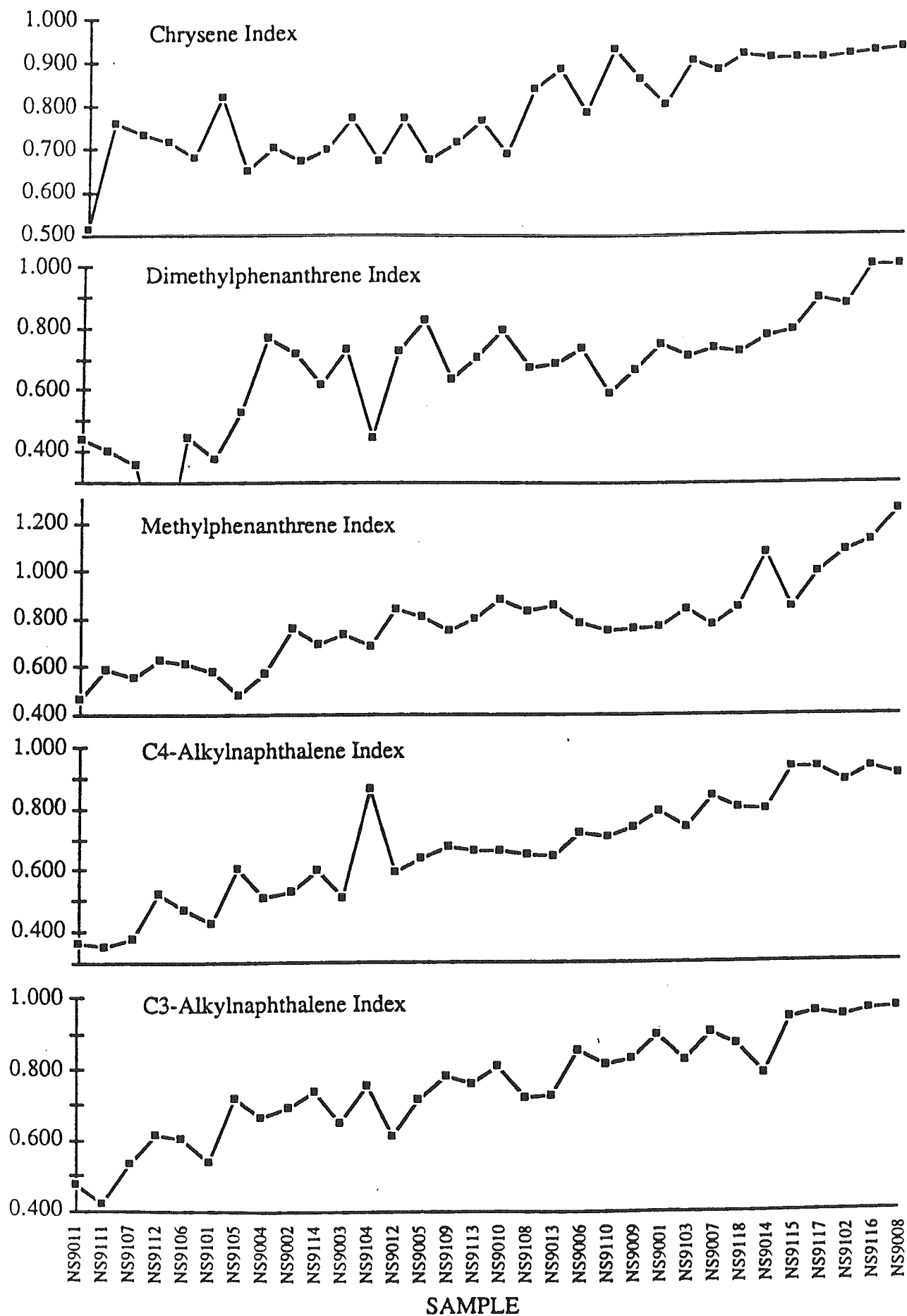
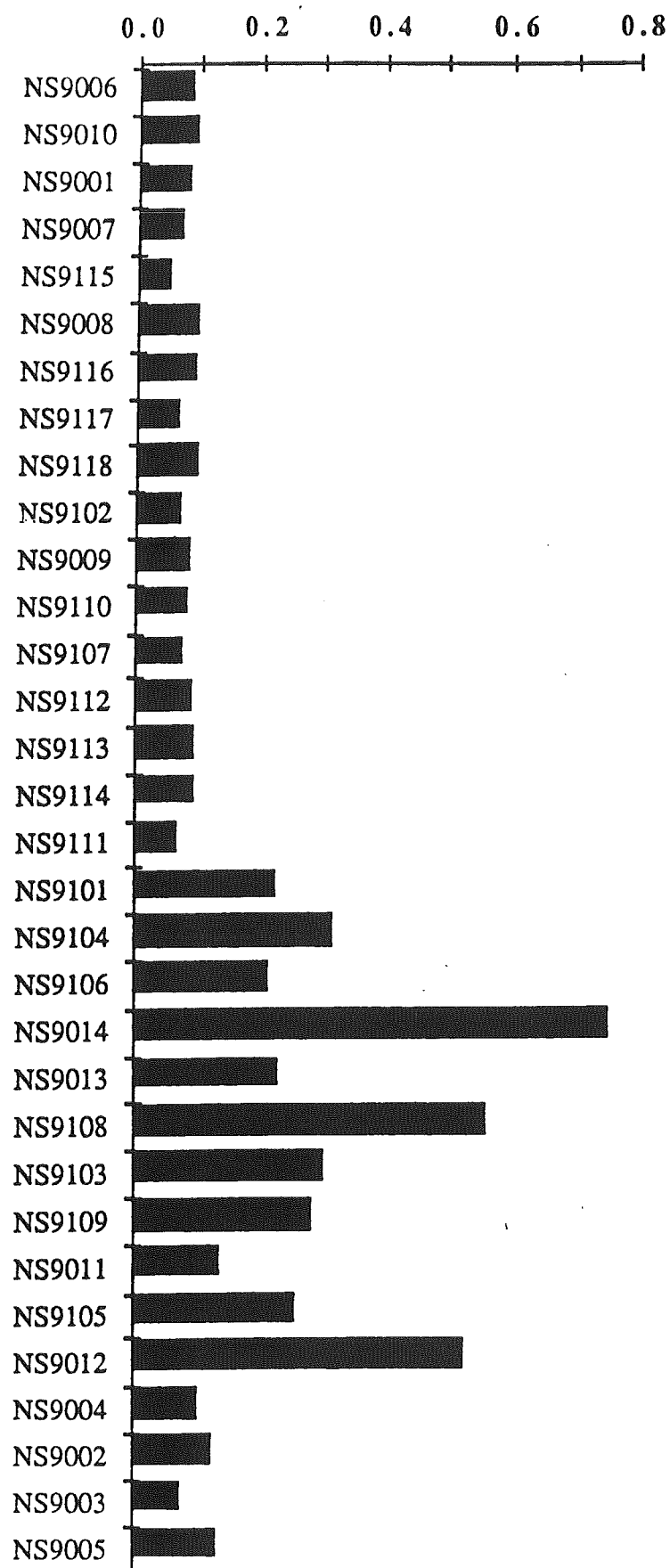


Figure 15 — Plots of aromatic maturity parameters; ranking established by scaling and averaging of all the parameters (see text).



Figure<sup>16</sup> — Sulfur content indicated by the ratio  $\Sigma$  thiophenes/ $\Sigma$  phenanthrenes. Samples are arranged in the same order as Figure 10.