88-2816

ANNUAL REPORT UPDATE
PRE-CONSOLIDATION REPORT

CONGA OIL PTY LTD
PROJECT D'ENTRECASTEAUX

LICENCES:
29/84;6/86;7/86;52/86;53/86
8/87;9/87;10/87;11/87;12/87;13/87;14/87;46/87

by

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CONGA-8A MAY 1988

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INTRODUCTION

This annual report update for Project D'Entrecasteaux by Conga Oil Pty Ltd in Southern Tasmania represents consolidated reporting for all adjacent licences in the region. A previous annual report was provided in August 1987.

This report has been prepared as part of the renewal-consolidation process for Conga's thirteen licences in Southern Tasmania. This followed recognition by all parties that the 13 licences comprised a single petroleum exploration project and that it would be best explored and administered by treating it as such. The present document thus brings up to date reporting of all exploration undertaken under the 13 grant regime; future reports will be referred to a single petroleum licence.

The consolidation will be accompanied by varied guidelines which, in the absence of a Tasmanian Onshore Petroleum Act, are based on those applying to similar exploration interstate. Thus application fees, rents, expenditure commitments, bonds and relinquishment conditions have been varied. Up to the date of consolidation all conditions and rents have been based on mineral exploration regulations which do not reflect the needs and costs of oil exploration.

A problem noted in the Annual Report of August 31, 1987 related to the erratic nature of grants and timing of work done. Even now, many of the licences are less than one year old but all work undertaken in association with the project, whether referred to pending areas or not, has been supplied and costed to the project.

The location of the licence areas is shown in Figure 1.

LICENCES

Held in the name of Conga Oil Pty Ltd, Southern Tasmania.

All are held for oil and coal.

PROJECT D'ENTRECASTEAUX

		applied	granted
29/84	Lagoon Hill, North Bruny	190584	100685
6/86	Catamaran	110386	250387
7/86	Southport	120386	250387
52/86	Bruny Island	231286	290487
53/86	Bruny Island	231286	290487
8/87	South Bruny	120287	180987
9/87	South Bruny	120287	180687
10/87	South Arm	120287	180987
11/87	Grove	120287	180987
12/87	Judbury	120287	180987
13/87	Waterloo	120287	180687
14/87	D'Entrecasteaux River	120287	180687
46/87	Boyer	30687	121287

Previous consolidated reporting date: August 31

All licences have been held under the Mining Act as mineral exploration tenements. This is an awkward and unrealistic situation for any onshore petroleum explorer and forth coming consolidation as a single licence will resolve most difficulties. The coal claims will remain under mineral issue and conditions.

EXPLORATION HISTORY AND OBJECTIVES

OUTLINE:

Since the preparation of the first "annual" report presented in August 1987 there have been a number of significant developments.

The first relates to the interpretation of regional gravity and magnetic surveys. This comprehensive study demonstrated that a complex basin history must be responsible for the evolution of the region. Ultimate, crystalline basement of Tyennan type is implied directly beneath Permian and Ordovician rocks west of the Picton River. Elsewhere basement is overlain by up to 3 km of denser, non magnetic and probably dolomitic units based on unit response correlations to the NW within the Jubilee region east of Lake Pedder. The boundary between other units was an active basin margin which can be related to a thick accumulation containing mafic volcanics. Marginal ultramafics are also implied and correlation with coastal exposures suggests Lower Cambrian (or Crimson Creek Formation) style units. Primary structures trend NNE or NW and Jurassic, Tertiary and modern structures and topography reflect these. The interpretation suggests the presence of wedges of Lower Palaeozoic rocks but further refinement is required before these are properly defined. There are also suggestions of fold patterns but not wavelength, closure or amplitude. The Cygnet dome is related to a large (up to 20 km diameter) pod of syenite about 2 km deep.

Further evaluation and application of the data or extension of the interpretation will depend on appraisal of Jurassic dolerite effects and their removal. In order to assist this process the magnetic properties of the dolerite have been reviewed.

The interpretation report is not included in this update due to its size. It, and the supplementary properties study, have been submitted separately.

In order to accelerate the programme and to guarantee high levels of long term funding Conga Oil was prepared for market listing. Mulready (Appendix 1) documented knowledge available at September 1, 1987. Although the listing attempt was ultimately prevented by market collapse a more significant problem attached to the credibility of the project. Mulready considered it a valid but high risk play well worth exploring due to the low infrastructure costs and need to find relatively small reservoirs.
Neither investors nor government advisers could accept, or acknowledge, Mulready's conclusions nor those held by the backers of the project, or myself, since they overturned 100 years of conventional wisdom about Tasmania. This largely reflected a belief that any oil generated onshore Tasmania must be related to the Permian oil shales. There is little doubt that if this is indeed the case then Tasmania's petroleum potential is effectively nil.

This conflict might never have arisen if the present chemical understanding existed (below).

During the period June to December 1987 several programmes related to reported seepages and the origin of the oil were instigated. Some are continuing; including the mud sediment study in Storm Bay and the D'Entrecasteaux Channel.

In the first of these an effort was made to confirm the original seep finding and analysis and trace other nearby reports. This search by Morrison (Appendix 2) provided a sample set for analysis, duplicate tests of the Johnsons Well site and also revealed that the previous attempts to drill earlier in this century had encountered oil - presumably by intersection of migration paths. These results prove that oil in reasonable volume was present and that critics desirous of an oil show in a drill hole need look no further.

The analysis of the samples confirmed the original analysis and demonstrated that the Johnsons Well site is not unique (Volkman, Appendix 3). The demonstration of hydrocarbons in water from an ephemeral stream (Miles Creek) indicates that some seepage is still occurring - even if not on the same scale as in 1900-10 or 1920-30.

Although not yet reported by Volkman work on Channel floor muds has revealed further hydrocarbons and the material is widespread in the Bruny-Channel region. It even appears that it may be concentrated along lineaments and certainly is onshore. All sites can be associated with Jurassic faults or contacts and some of these appear to possess deep penetration (based on preliminary 3D modelling).

None of this work could explain why the seepages appear to have been sporadically reported, nor establish the origin of the oil. Morrison discussed some of the issues as he saw them (Appendix 2). The facts upon which his discussion is based are to be found in Appendices 3 and 4. Overall Morrison took the long term view even though the Permian oil shale could be positively dismissed. Volkman was clear on this point since the seep samples lacked the Permian shale biomarkers.

Earthquake data, although necessarily incomplete prior to 1960, suggests part of the solution to the enigma (Appendix 5). Tasmania has been seismically quiet for nearly 30 years with few events of intensity 4 or greater. Yet swarms of these events were felt toward the end of the last century and in the third decade of this. These periods coincide with the most frequent reporting of seeps or presumed seeps. If this is assumed to be a valid correlation then leaking reservoirs, tight migration paths and a pre-Permian source are implied.

Analysis of Ordovician Gordon Group Limestones, however, shows that the characteristics of Ordovician limestones (universal), these limestones and the seep samples (onshore and in the channel muds) are consistent (Volkman, Appendix 6 - p.24).

Although there remains scope and need for further work several points can be made.

1. The hydrocarbons found have not been sourced by Permian oil shales. None are known in the area in any event.

2. The hydrocarbons appear to the released by seismic activity.

3. There is strong evidence for an Ordovician source; namely Gordon Group, based on chemical, maturity, conodont and implied depth criteria.

4. The hydrocarbons carry significant marker compounds - methyl hopanes. These control source age range and offer a means for regional mapping and confirmation of reports.

5. No argument can be supported for local Permian or shallower derived material as source based on local over maturity due to intrusions. There is not only no evidence of this but the distribution of established occurrences precludes such an origin.

The chemical evidence already available in this "high risk", unknown region is better than for many producing provinces. This evidence coupled with the basin study indicates that the source rocks are present and possibly widespread beneath the base Permian unconformity. The unconformity is clearly an excellent seal.

Much of Conga's effort to date has been directed at overcoming a century-old credibility gap rather than seeking structures which might be a more normal approach and which could be considered acceptable elsewhere as a scratch programme - and it should be in this area, now.

No drilling will be considered until appropriate structures have been defined.

A seismic test on Bruny Island has demonstrated that the method can be employed, that the dolerite sheets need be no barrier although definition of the dolerite base is poor - a property noted in the Fingal region. The results of the test line (Appendix 8) are consistent with the gravity/magnetic interpretation; no stratified sub Permian section but tightly folded late Precambrian or Precambrian basement (at 2 secs or 3 km approx). The processed section is also reproduced in Appendix 8.

Appendix 7 provides the complete gravity data base for surveys undertaken in 1987 and interpreted. All magnetic and gravity data have been supplied to the Department in computer readable and map forms.

PROGRESS FROM AUG 31 TO DATE:

1. Seepage reports have been confirmed and analyses replicated.
2. Seepages have been confirmed across a wide area.
3. Compounds found in samples indicate an Ordovician origin for the oil. The compounds have been matched with organic materials in Gordon Group limestones.
4. Permian oil shales cannot be source rocks for these hydrocarbons and that maturity of Permian rocks is inconsistent with them.
5. Circumstantial evidence from seismic data suggests that seepages, or reports of them, are related to events or swarms of events of intensity 4 or greater.
6. Eyewitness evidence of recovery of hydrocarbons during the 1930 drilling programme.
7. Onshore seismic practice, including the effect of dolerite and the nature of pre-Permian units on Bruny Island, has been assessed.

PROGRAMMES IN PROGRESS:

1. The seep search programme for location of all reported sites and sampling is continuing. If other sites can be confirmed and some patterns established between seepage sites and structural interpretations it is believed that problems of target priorities will be greatly eased.
This programme will includes both sea bed and land searches and complete analyses of recovered samples.

2. A detailed structural interpretation of the gravity-magnetics data base is underway, but temporarily halted until an improved focus for targetting is available, which should provide orientation guidance for seismic surveys and a general view of the basin as well as suggesting structure and prospect patterns within it. The initial stratigraphic well will be based on the preliminary stage of this work.

3. Source rock sampling and analysis. This work is to follow up results reported here and to indicate which members of the stratigraphy are the primary sources. The difference between reefal or back reef members may ultimately be important.

4. Review of basement lithologies and distribution as revealed by content of Permian tillites and basal conglomerates, and Tertiary pyroclastics. This study is designed to support the development of basement composition studies derived from regional geophysical data until adequate regional seismic cover and drill control become available. The results may be used in association with the seepage study and the first phase of regional interpretation to site the initial well.

PROGRAMMES PROPOSED:

1. A regional stratigraphic and palaeontologic compilation to assist well sample identifications.

2. Review of the marine seismic data acquired by the Bureau of Mineral Resources during April 1988. Some 300 km of data of interest to Conga Oil has been acquired. Conga Oil has cofunded acquisition of this data for research and the material will be released as part of the normal policy of the BMR. The use and interpretation of the data will be inhouse.

SUMMARY OF EXPLORATION OBJECTIVES

Recent work has demonstrated that the region has petroleum potential and should be explored. The presence or Ordovician-sourced hydrocarbons means that the so - called Tasmania Basin can no longer be considered a post Permian backwater with no potential - especially when it is known that the sourcing limestones possess secondary porosity and could be sealed by the base Permian unconformity.

Issues to be further evaluated include:

SOURCES:
Detailed review of Upper Cambrian to Lower Silurian rocks to identify specific or multiple sources or sourcing members within the Gordon Group.

ASSESS SCALE OF GENERATION OR MIGRATION:
This problem is partly related to the nature of the source. However, any distribution of seepages or source indications upon analysis of such seepages will be critical. It is hoped that these indicators might be tied to inferred lithology distribution as suggested from the geophysical or pyroclastic studies.
Although present work is incomplete there is considerable spread in potential seepage sites. Most identified to date lie east of the western margin of the Lower Palaeozoic basin and could be located on Jurassic fracture intersections with the west dipping unconformity.

PLAY DEFINITION:
Preliminary work to date suggests the presence of fold closures, rejuvenated troughs, unconformity seals, shelf deposition, rift margin rise shoulders and dolerite traps. Each of these feature styles will need to be defined, rated and drilled. Rating will be affected by inferred rock distributions and migration considerations and seismic data is likely to be essential to such appraisals. The economics and practicability of seismic methods has been established in this environment but the high cost (approx $7000/km) will mean limited coverage and that traverses must be specifically located on other indicators (chemistry, seepages and gravity/magnetics).

OVERALL:
To evaluate the region in such a way as to rationally assess its potential for Conga's purposes or to aid future explorers.

EXPENDITURE SUMMARY

The table below is applied to the set of licences as if consolidated. Note that not all licences have yet applied for a full year and that there is some administrative bias in the figures although now much less than noted in the August 31 summary.

The figures provided apply to the reconstituted Conga Oil (from April 7, 1987 - see August 31, 1987 discussion) and thus refer to a full year of exploration.

Geology (regional appraisals, seep search, feeder location, consultants, etc)	$27543
Geochemistry (analyses)	16141
Geophysics (regional study, data acquisition interpretation in progress)	165321
Drilling	0
Administrative overheads (licence fees, accounting, management)	40935
Other (Drilling engineering, consultants, maps sundries, surveying etc, staff labour)	31069
Total:	281009

The company has also spent $582238 on a drilling rig with a capacity of 3500 m. This was obtained at the bottom of the market and is a major asset. It was acquired to keep the spirit of a commitment to drill this region but it will not be used until imported from the US and a satisfactory site has been selected. Other costs associated with the project amount to about $350000 but these cannot be charged according to the guidelines.

The total expenditure directly costed or related to the project is in excess of one million dollars to date and should be considered more than adequate fulfillment of any commitment on an area previously thought to be unworthy of the effort. The bona fides of Conga Oil should be beyond question for the immediate future.

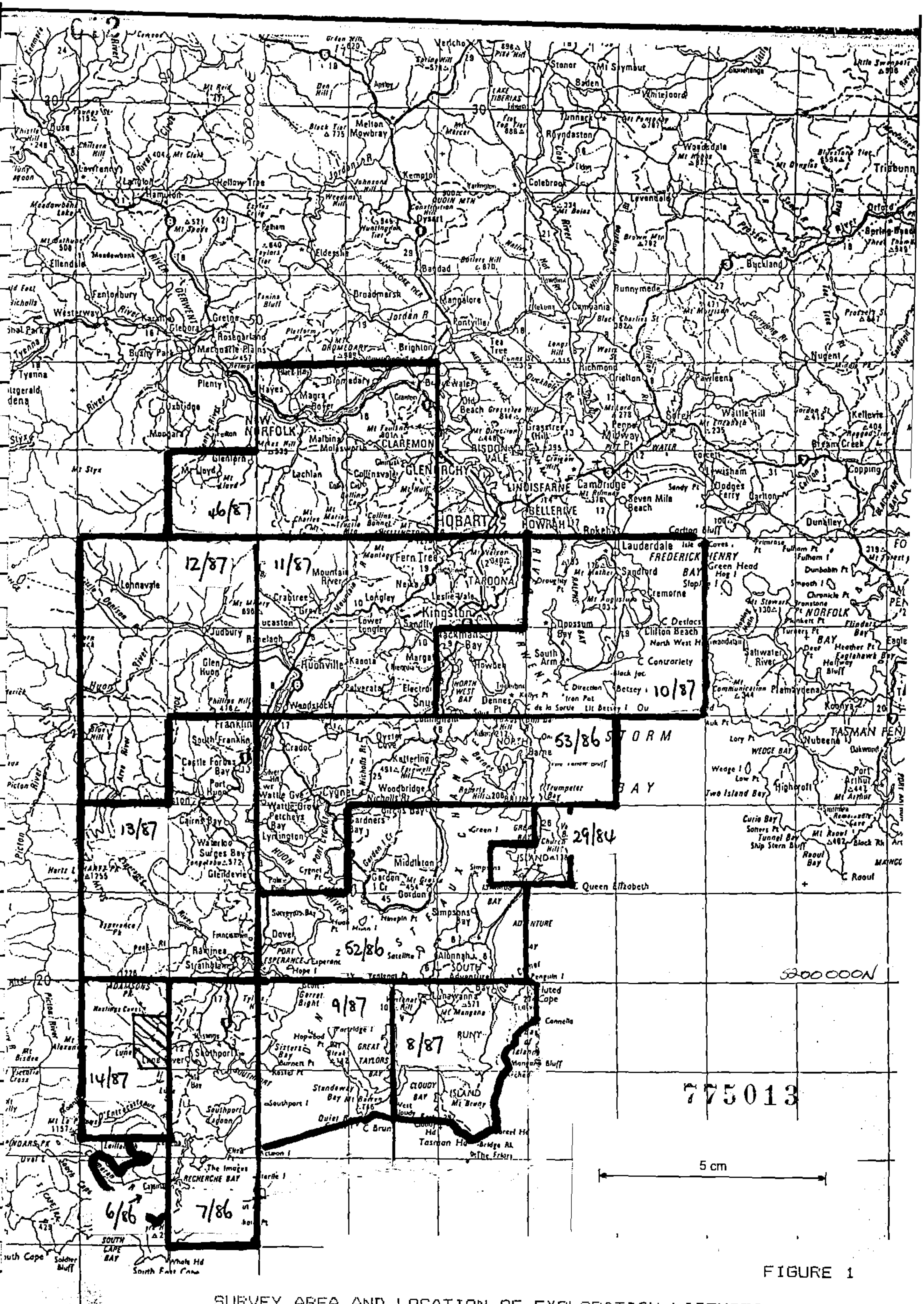

FIGURE 1

SURVEY AREA AND LOCATION OF EXPLORATION LICENCES

APPENDIX 1

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REVIEW

CONGA OIL EXPLORATION PERMITS

SOUTH EASTERN TASMANIA

J. N. Mulready

September, 1987.

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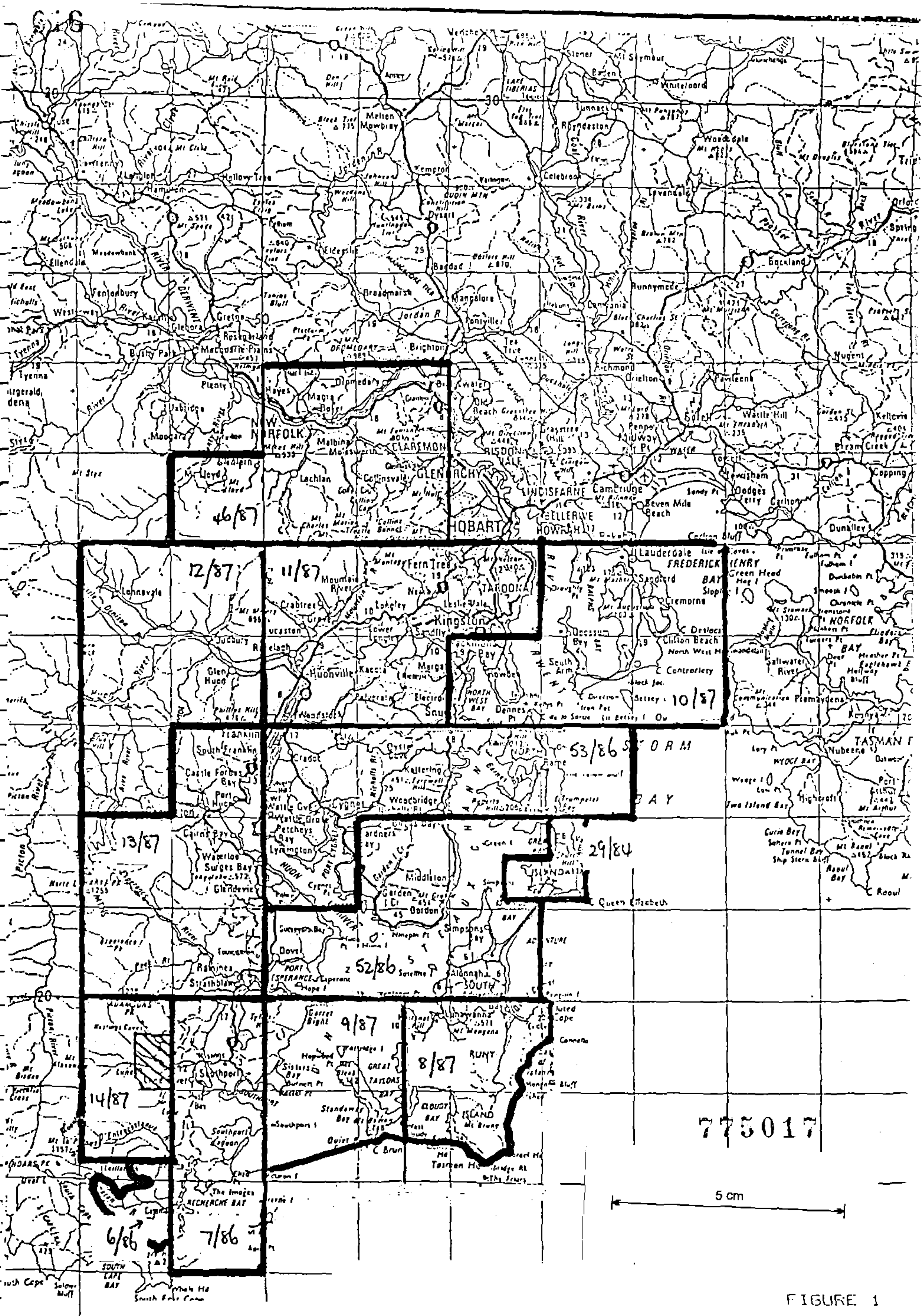

FIGURE 1

SURVEY AREA AND LOCATION OF EXPLORATION LICENCES

INTRODUCTION

The following licences are held in the name of Conga Oil Pty. Ltd., and are located in south-eastern Tasmania, immediately south of Hobart (refer location map). They include North and South Bruny Islands, much of S.E. Tasmania onshore as well as much of the D'Entrecasteaux Channel and Storm Bay. All are held for both coal and oil.

		Applied	Granted or Status
29/84	Lagoon Hill, North Bruny	19/5/84	10/6/85
6/86	Catamaran	11/3/86	25/3/87
7/86	Southport	12/3/86	25/3/87
52/86	Bruny Island	23/12/86	29/4/87
53/86	Bruny Island	23/12/86	29/4/87
8/87	South Bruny	12/2/87	18/9/87
9/87	South Bruny	12/2/87	18/6/87
10/87	South Arm	12/2/87	18/9/87
11/87	Grove	12/2/87	18/9/87
12/87	Judbury	12/2/87	18/9/87
13/87	Waterloo	12/2/87	18/6/87
14/87	D'Entrecasteaux River	12/2/87	18/6/87
46/87	Boyer	3/6/87	*

* Pending.

NOTE: Under present legislation all onshore oil exploration licences must be held as mineral tenements.

Preliminary investigations involving

a) Location and evaluation of reported hydrocarbon seeps

b) Sampling and analysis of outcrops of Ordovician age Gordon River Limestones within south-eastern Tasmania, and

c) Interpretation of regional magnetic and gravity data

commenced in early 1986: additional licence areas were applied for as the implications of these preliminary investigations became apparent.

Exploration results to date suggest that a substantial Palaeozoic sequence may be preserved beneath the base-Permian unconformity in parts of south-eastern Tasmania. By analogy with the known geology of western Tasmania it is anticipated that this sequence will be Cambro-Silurian/Devonian in age, with possible sourcing of hydrocarbons attributed to either the Ordovician carbonate sequence (Gordon Limestone) or the Permian Lower Parmeener Supergroup. Possible reservoirs are the Silurian clastic sequence, (Eldon Group), possibly enhanced by epidiagenesis at the base-Permian unconformity, and the source sequence itself, (Gordon Limestone).

The structural style is expected to involve both folding and thrusting, as well as complications arising from doleritic intrusions. Detailed analysis of aspects if not yet possible with the data presently available.

REGIONAL GEOLOGY

Tasmanian geology is characterized by a basic two-fold subdivision into a region of Pre-Cambrian and Lower Palaeozoic rocks outcropping in Western Tasmania and a region of Lower to Mid Palaeozoic rocks of contrasting facies which outcrop in north-eastern Tasmania. The boundary between these two regions is obscured by an extensive cover of Permo-Triassic sediments and Jurassic dolerite which extends over most of South-East and Central Tasmania.

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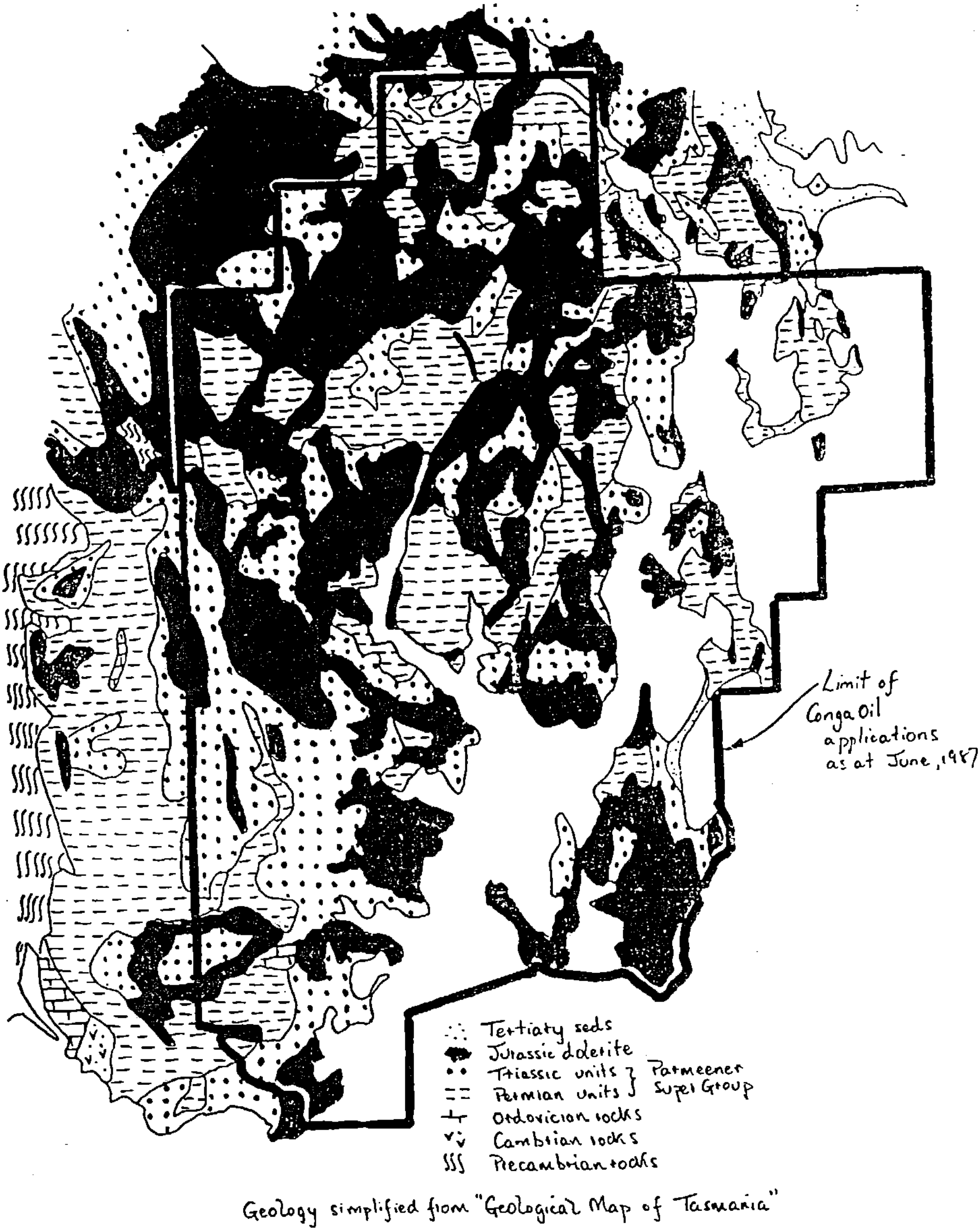
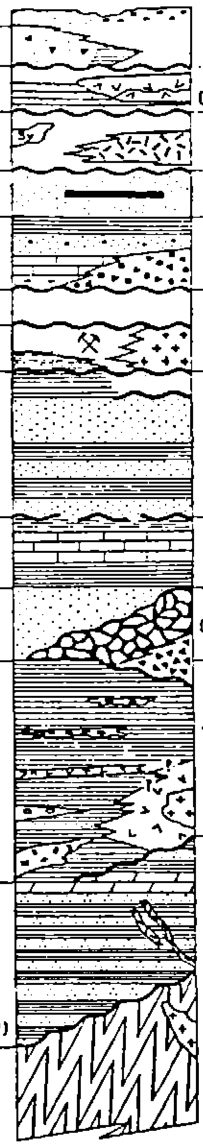


FIGURE 2

PRINCIPAL GEOLOGICAL ELEMENTS OF THE REGION

TABLE 1 GEOLOGICAL COLUMN, TASMANIA (Solomon)



SEDIMENTS	AGE	THICKNESS IN FEET x10³	TECTONIC AND IGNEOUS ACTIVITY
Alluvium, gravels	Recent		
Moraine, varved clays	Pleistocene		UPLIFT
Non marine sand, lignite, clay; marine limestone	Tertiary	0-1	Basalt Flows, Volcanic Necks; HORST & GRABEN STRUCTURES; Bauxite Formation
	Cretaceous Jurassic		Syenite at Cygnet; Intrusion of Dolerite sill(s)
Sandstone, siltstone, coal measures	Lower Jurassic to Triassic	2	
Pebbly sandstone, mudstone, paraconglomerate, limestone, basal tillite	Permian	3	Volcanic Ash ?
	Carboniferous		UPLIFT & EROSION
Eugenana Beds, cave filling	Middle Devonian		Granite Intrusion, mineralization (Rosebery Lyell Aberfoyle etc.); TABBERABBERAN OROGENY (Late Lower Devonian to Late Middle Devonian)
Eldon Group, Mathinna Beds, sandstone, shale	Lower Devonian to Silurian	10	
			BENAMBRAN OROGENY (?)
Junee Group, Siltstone, Gordon Limestone, Florentine Valley Mudstone	Ordovician	6	
Caroline Creek Sandstone, Owen Conglomerate, Jukes Breccia	Lower Ordovician to Upper Cambrian	0-5	JUKESIAN FAULTING (& FOLDING ?) TROUGH & RIFT VALLEY (?) DEVELOPMENT
Dundas Group, Huskisson River & Crimson Creek Successions, mudstone, paraconglomerate, spilite, siltstone etc.	Upper to Middle Cambrian	10 to 20	FAULT MOVEMENTS; Mt Read Volcanics, Murchison River & Darwin Granites: may unconformably underly Middle Cambrian (Campana et al.); Intrusion of Serpentinites into base of Dundas Group ?; PENGUIN MOVEMENT
Rocky Cape, Corbine Groups, Oonah Formation, quartzite, shale, dolomite	Younger Pre-Cambrian (Part Lower Cambrian ?)		Dolerite Dykes (Proterozoic or Cambrian); FRENCHMAN OROGENY; Granite Intrusion - pre Middle Cambrian
Franklin, Mary Groups etc., schist, quartzite, amphibolite etc.	Older Pre-Cambrian		

TABLE 2 GENERALIZED STRATIGRAPHY

LITHOSTRATIGRAPHIC UNIT		LITHOLOGY	ECONOMIC CHARACTER	AGE
PARMEENER SUPERGROUP	UPPER (300 m)	Quartz arenites Lithic wackes	Suitable seals	TRIASSIC
PARMEENER SUPERGROUP	LOWER (300 m)	Coals Glacio-marine silts, shales and sandstones. Tillite	Possible source rock (immature ?)	UPPER PERMIAN LOWER PERMIAN
	ELDON GROUP(40m)	Quartz arenite	Possible reservoir	U.ORD.- L.SIL.
GORDON GROUP	PRECIPITOUS BLUFF BEDS (230 m)	Shales and micrites	Possible source rocks	UPPER ORDOVICIAN
GORDON GROUP	NEW RIVER BEDS (380 m)	Platform margin Calcarenite and calcirudites	Possible reservoir	UPPER MIDDLE ORDOVICIAN [BLACKRIVERAN]
GORDON GROUP	CASHIONS CREEK (150 m)	Algal limestone	Possible source rocks	LOWER MIDDLE ORDOVICIAN
GORDON GROUP	KARMBERG (100 m)	Nodular limestone		LOWER MIDDLE ORDOVICIAN
DENISON GROUP		Quartz arenites		LOWER ORDOVICIAN
		Turbidites	Possible source rocks?	CAMBRIAN
		Dolomites Quartzites		PRE-CAMBRIAN

Ex Burret Uni.of Tas.

Accordingly the nature of the Pre-Permian section in South-East Tasmania is obscure, and there have been few deep stratigraphic tests to shed light on this question. The Conga Oil permits are located in South-Eastern Tasmania, within the region characterized by Permo-Triassic outcrop and dolerite intrusives, (refer Figure 2).

Extensive folding occurred in the Devonian and there has been subsequent faulting and igneous activity in both the Jurassic and Late Cretaceous? to Early Tertiary.

STRATIGRAPHY

The geological column of Table 1 summarizes the Tasmanian sedimentary section. Table 2 is a generalized stratigraphic table for southern Tasmania.

STRUCTURE

Evidence for the existence of low relief geanticlines is first evident in Pre-Cambrian sediments. During the Cambrian these features became emergent. The overall structural style is tensional (horst-graben) with associated narrow depocentres forming on the flanks of the geanticlines, accompanied by widespread volcanic activity.

Ordovician tectonism accentuated the horst-graben type tectonics, and initial conglomeratic sedimentation was followed by deposition of carbonates (Gordon Limestone). Deposition continued from the Ordovician until the Devonian; the SiluroDevonian sequence was probably far more extensive than the graben-basins characterizing the Cambrian and Early Ordovician. The marine clastics of the Eldon Group are considered to have exceeded 10,000' in thickness in parts.

Ensuing Devonian orogeny caused major uplift and deformation (folding and faulting) along dominantly NW or NNW trends, followed by extensive erosion. The 'younger' sediments (Ordovician and Siluro-Devonian) are thus preserved only in the cores of the eroded synclinoria, whilst the Cambrian, although less extensive originally, is more extensively preserved.

The resultant erosional surface prior to the resumption of deposition in the Permian was characterized by extensive relief. The angular unconformity at the base of the Permian is one of the most spectacular features of Tasmanian geology. Permo-Triassic sediments above the unconformity are sub-horizontal, (the unconformity dips at 5-10° due to Tertiary epeirogenic movements), and overlie folded and eroded Palaeozoic rocks (refer Fig. 3). As Fig. 3 illustrates, the Lower Palaeozoic sub-crop is likely to be erratic, and in the absence of well-control geophysical investigations provide the only feasible means of predicting its occurrence. From the Permian onwards tectonic activity consisted mainly of gravity faulting and concomitant hypabyssal intrusion and volcanism. Sedimentation, both marine and terrestrial, was relatively thin. Raised shore platforms and rejuvenated rivers suggest recent uplift for much of Tasmania, but this was preceded by partial drowning, which produced a highly indented coastline in the south.

HYDROCARBON POTENTIAL

Exploration History

Tasmanian oil exploration has been concentrated almost exclusively on the offshore Triassic-Cretaceous sequence, particularly the Bass Basin off Northern Tasmania.

By contrast the onshore basins have been largely neglected as a result of -

a) Extensive mineralisation in Western Tasmania
b) Widespread dolerite over much of Central and Southern Tasmania
c) An assumption that only Permian sourcing was viable, combined with a relative dearth of Permian or post Permian sealed reservoirs.

Accordingly onshore drilling has been limited to mineral exploration core-holes or water bores, with some limited deeper stratigraphic holes drilled by the Tasmanian Department of Mines. However hydrocarbon seepages have been reported at several sites in Southern Tasmania since the turn of the century. Only the seep at Johnson's bore on North Bruny Island was taken seriously, and an attempt was made to evaluate the significance of the seep by drilling some fifty years ago. The hole was apparently abandoned at shallow depth after the casing collapsed.

EL 29/84 was initialy taken out with the intent of evaluating the North Bruny seep. By the end of 1986 there were strong indications, based on geochemical analysis of limited sampling, (refer Appendix 1), that the Johnson bore seep was genuine. This has subsequently been confirmed by additional sampling. At the same time a University of Tasmania study of conodont thermal alteration indices in the Ordovician Gordon Limestone and a recently discovered Cambrian Limestone on the south coast indicated that both these units lie within the oil window. Subsequent interpretation of available aeromagnetic and gravity data strongly suggested the presence of a substantial Lower Palaeozoic section beneath the Permian and dolerite, and it was decided to conduct a combined aeromagnatic and gravity survey in order to improve the data base for interpretation.

Source Potential

Three possible sources for hydrocarbon generation can now be postulated:

1) Cambrian carbonates

2) Ordovician carbonates

3) Permian coal and shale sequences.

As mentioned previously, conodont studies reveal that the first two possibilities lie within the oil window: organic carbon contents are low, but this is not abnormal for weathered outcrop samples of carbonates. Elsewhere in Tasmania tar and pitch occurrences are noted in Lower Palaeozoic carbonates.

Permian sediments of the Lower Parmeener Sub-group have possible source potential in northern Tasmania, but in Southern Tasmania facies changes may severely limit their potential. Additionally, their thermal maturity is suspect, although this may be locally elevated by proximity to igneous intrusives, but probably on a restricted scale.

Reservoir

Three possible ~~source~~ reservoir rocks have been identified:

1. Basal sediments of the Permian Parmeener Supergroup. It is possible that localized conglomerates developed on the unconformity surface could be viable source rocks.

2. Siluro-Devonian Eldon Group sandstones underlying the unconformity, (with possible epidiagenetic enhancement of reservoir quality).

3. Calcarenitic upper parts of the Ordovician limestone sequence, with

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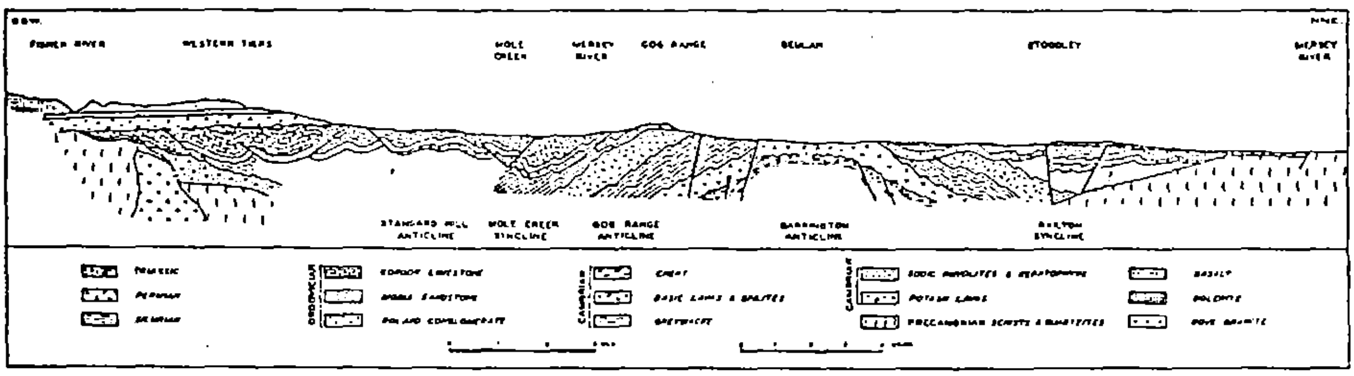


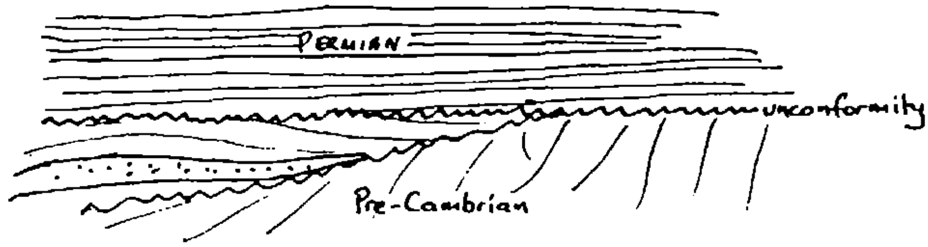
Section through the North-West Coast (I. B. Jennings).

5 cm

FIGURE 3

PRE CARBONIFEROUS SECTION: SUMMARY OF RELATIONSHIPS
(from Geology of Tasmania, J.geol.Soc.Aust., 9, 1962)

1) Stratigraphic Traps where post-Cambrian units onlap basement and are sealed by overlying Permian sediments and/or dolerites.

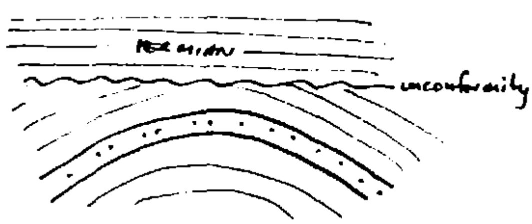


2) Truncated folds - beneath the unconformity

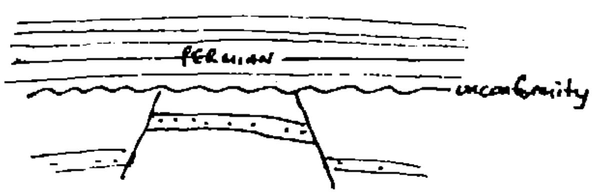
Strike Section

Dip Section

3. Anticlinal domes



4. Fault Traps



5. Basal Permian Stratigraphic Traps

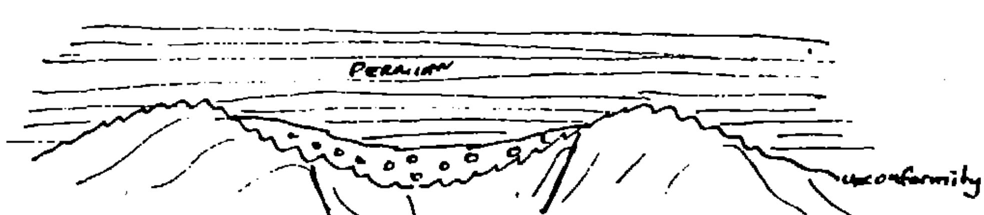


FIGURE 4

possibly secondary porosity development.

Some thin section studies have been carried out on these units, but definitive sub-surface core samples and well-logs will be required before reaching any conclusions regarding their ultimate potential. Note however that data from the Mereenie field, Amadeus Basin, suggest that lower range porosities for similar age sediments are capable of significant oil and/or gas flows.

Seals

Include Ordovician or Silurian shales, Permian mudstone/tillite, or even dolerite.

Entrapment

Geophysical interpretations and analogy with western Tasmania suggest there are two possible structural styles, as postulated by Leaman[1] (1987), viz. plunging folds or overthrust blocks. A variety of possible trap types can be envisaged which are consistent with these structural problems. Some of these are illustrated in Figure 4.

Vertical migration up faults and along the unconformity may be significant factors in filling such traps. Jurassic faulting is heterogeneous - some faults do not penetrate below the unconformity, some were sealed at the end of the Jurassic dolerite intrusion, whilst in other cases Tertiary re-activation may render some Jurassic faults 'leaky'. It should be noted that geophysical evidence (Leaman) suggests the permit area has been little affected by Cretaceous and Tertiary faulting (unlike many other parts of Tasmania) and appears to have been relatively stable since the Jurassic. This has significant implications for the integrity of the post-Jurassic seals, which are essential to entrapment of hydrocarbons generated in Cretaceous or Tertiary time. The likely 'leakiness' of some of the faults suggests that gas accumulations would be less effectively trapped because of their greater relative permeability compared with liquid hydrocarbons. The integrity of the seals is one of the major risks associated with the play.

The age of generatiion relative to trapping is significant in determining the validity of the play. Leaman argues for Jurassic-Cretaceous generation, and considers that this area has suffered little subsequent Cainozoic disruption.

Conga Oil's exploration programme is still at a very early stage of development.

The results to date may be summarized as follows:

1. Stratigraphic relationships are already documented for the Permian section, and adjacent stratigraphic information relating to the Early Palaeozoic section (Ordovician-Silurian) has been 'extrapolated' into the permit area to suggest a possible source (Gordon Group carbonates) and reservoir (Gordon Group carbonates and Eldon Group sandstones), as well as explain the seep.

2. Conodont colouratiion studies in relation to these potential source rocks indicate a level of maturity (CAI values ranging from 1.5 to 2) which places them in the oil-generation 'window'.

3. A sample from the Johnson well seep when analyzed is quoted as having a similar level of maturity to that suggested by the conodonts, and is also regarded as having been derived from a carbonate source-rock (refer Appendix 1).

---

[1] Consulting geophysicist, Hobart.

4. Interpretation of thermal magnetic and gravity data (Leaman 1986) indicated that a structured and variable pre-Permian sequence exists within the permit areas. Subsequent magnetic and gravity data acquisition has extended the data base. A detailed structural interpretation of the gravity-magnetics data base is underway which should provide orientation data for seismic and a general view of the basin as well as suggesting structure and prospect patterns within it.

PROPOSED EXPLORATION PROGRAMME

1) It is recognized that development of the exploration play will require acquisition of seismic as an urgent early priority. To this end limited experimental seismic is being shot within the permit area utilizing Tasmanian Mines Department equipment. Preliminary planning for seismic envisages offshore coverage in the D'Entrecasteaux Channel and Huon estuary in order to provide regional coverage, to be complemented by onshore coverage where terrain, access and surface conditiions permit.

2) Attempts are being made to locate and sample additional seeps, and assess their significance for oil generation and migratiion. Additionally source rock sampling of outcropping Lower Palaeozoic limestones will continue, and some sea-bed sampling will also be included, in co-operation with the CSIRO.

3) A review of basement lithologies and their distribution, as revealed by the content of Permian tillites and basal conglomerates, is under way. This study is designed to support the development of basement composition studies derived from regional geophysical data until adequate seismic and sub-surface control become available.

4) The exploration play outlined above is based on the assumption that a Palaeozoic section is present beneath part of the permit area, beneath the base-Permian unconformity. In order to establish the exact nature of this sectiion, as well as to gain more definitive data regarding source and reservoir potential, it is intended to locate an early stratigraphic well where geophysics suggest the most favourable subcrop thicknesses. Additionally, log and other well data will be essential for calibration of geophysical techniques, particularly seismic. Conga Oil will drill using its own rig, capable of drilling to 4000 m. The exact location of the well will need to await the results of the geophysical interpretation (magnetics, gravity and experimental seismic).

ECONOMICS

The location of Bruny Island in such close proximity to Hobart (although this city does not at present have a refinery), and with easy access to shipping facilities, suggests that even a moderate to small size oil-field (1-2 million bbl) or alternatively a moderate size gas-field would be most attractive in a commercial sense. Transportation costs are likely to be minimal, since the permits are located near to the coast and thus within close reach of Victorian refineries by sea.

Preliminary economic analysis suggests that even a small to medium initial discovery would have a net present value of over $10 million pre-tax.

CONCLUSIONS

1) Geophysical data and analogy with Western Tasmanian geology suggest that troughs containing Lower Palaeozoic sediments should occur beneath the base-Permian unconformity in south-east Tasmania. There is also some geophysical evidence for structuring, although resolution of the style is not yet possible.

2. Source.

Geochemical data suggests the most likely candidate is the Ordovician Gordon Limestone. Cambrian Limestones and Permian shales are also possibilities. Sampling and analysis of seeps suggest that oil has been generated within the region, although at this stage it is not possible to draw quantitative conclusions or construct meaningful migration paths.

3. Reservoirs could be associated with Silurian sandstones, Ordovician limestones or basal Permian conglomerates.

4. Seals may be provided by the Permo-Triassic section or even the dolerite.

5. Any discovery is likely to have very favourable development and transport costs due to the location of the permits. The Conga Oil permits cover the area of a valid but high-risk exploration play, which it is intended to investigate at the earliest opportunity. The exploration programme envisaged includes stratigraphic drilling at an early stage, as well as seismic. Major problems relating to seismic acquisition are anticipated and these will need to be overcome if exploration is to proceed at a viable pace.

APPENDIX 1

GEOCHEMICAL ANALYTICAL RESULTS

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CSIRO
MARINE LABORATORIES

Division of Fisheries Research
Division of Oceanography

A Division of the Institute of Animal and Food Sciences
A Division of the Institute of Physical Sciences

Castray Esplanade, Hobart, Tas. 7000

GPO Box 1538, Hobart, Tas. 7001
Telephone (002) 20 6222 Telex AA 57182
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April 13th, 1987

Dr. D. Leaman
Consultant Geophysicist
Leaman Geophysics
G.P.O. Box 320D
Hobart
Tasmania 7001

Dear David,

I much appreciated your visit this morning to inform me of latest developments regarding proposed oil drilling on Bruny Island by Conga Oil.

As you now know, my only interaction with Mr. Bendall has been to assist him in the interpretation of organic geochemical data obtained on a mud sample from Bruny Island which he believed contained petroleum residues originating from an oil seep. I presume that my advice was sought since I have experience in the application of organic geochemistry techniques to petroleum geochemistry and I have published quite a few scientific papers in this field. Such expertise seems to be sadly lacking in Tasmania so I was happy to assist Mr. Bendall in this way.

I think that it is important to document my main findings concerning the geochemical data for the oil seep sample obtained by Analabs in Perth, so that there can be no misunderstanding about the information that I gave Mr. Bendall. My interpretation is limited by the fact that I was not involved with the collection of the oil seep sample, nor did I carry out the geochemical analyses. You should also be aware that the sample was not very suitable for organic geochemical analysis due to the low amounts of hydrocarbons present and high proportion of biologically produced hydrocarbons. Analyses of such materials can be very difficult to interpret due to possible changes in oil composition during migration, and subsequent biodegradation where the oil comes to the surface.

My main findings are:

(1) The mud sample contains a mixture of hydrocarbons, most of which are derived from vascular plants. However, the gas chromatogram of the saturates does show the presence of shorter-chain alkanes with no odd-over-even predominance, together with pristane and phytane that are more commonly associated with petroleum. Stereochemical analysis of the isoprenoids would be needed to confirm their petrogenic origin.

(2) Biomarker analyses of this sample by Analabs using gas chromatography-mass spectrometry also shows evidence of recent biogenic hydrocarbons superimposed on a distribution of steranes and hopanes that are from a thermally mature source. These compounds are quite minor components of the extractable hydrocarbons, but their presence is consistent with an oil seep. I agree with the suggestion by Analabs based on sterane ratios that the maturity of the presumed source of this petroleum corresponds to a vitrinite reflection of about 0.75 (i.e. well into the oil window).

(3) An unusual feature of the distributions of biomarkers is the presence of a series of alkyl cyclohexanes. These are abundant in only a few oils, and it has been noted that they appear to be associated with Ordovician carbonates or evaporitic facies. However, this is not proof that the petroleum originated from a carbonate sequence. The GC-MS data provided by Analabs is limited to a single m/z 83 mass fragmentogram with only one compound identified in the series so I would like to see further work done to confirm these identifications. These data should then be compared with those obtained for presumed source rocks to confirm the source of the oil.

(4) The presence of hydrocarbons covering a wide range of molecular weights including both short-chain alkanes, alkyl cyclohexanes and high boiling steranes and triterpanes is consistent with a crude oil rather than a refined petroleum product. Mr. Bendall assures me that there is no possibility that this petroleum could have originated from human activity, such as a farmer dumping sump oil or other petroleum product, but it would be prudent to analyze other seep samples to confirm that the hydrocarbons are not from pollution.

(5) Analabs reported high concentrations of aromatic hydrocarbons in the mud sample. Naturally produced aromatic compounds can be found in sediments but high concentrations of aromatics are usually due to pollution or petroleum residues. These aromatic hydrocarbons should be characterised by gas chromatography-mass spectrometry to see whether the distributions are consistent with inferences drawn from the saturated alkanes. Parameters are now available to determine the maturity of the oil based on the proportions of methyl phenanthrene isomers.

(6) These preliminary data are thus consistent with an oil seep, but additional samples from this site and other seeps on Bruny Island and surrounding areas should be studied to confirm this. Care should be taken to exclude plant matter from the sediment sample (e.g. by sieving) since biogenic hydrocarbons from this source are much more abundant than petrogenic hydrocarbons in the

sample that I looked at. It is apparent from the high noise level in some of the mass fragmentograms produced by Analabs that they had difficulty in detecting some of the petroleum biomarkers and they were not able to calculate all the biomarker parameters that are usually included in a geochemical assessment of a petroleum sample. I also feel that it would be wise to establish the geographic distribution of oil seepage before a concerted drilling program is undertaken.

I stress that the geochemical data obtained to date are not adequate to characterise the source of the petroleum hydrocarbons found in the mud sample from Bruny Island.

As mentioned in our discussions, staff from my research group in the CSIRO Division of Oceanography and a student from the University of Tasmania have been undertaking a small project studying the organic constituents of sediments from D'Entrecasteau Channel to determine the relative contributions from seaweeds, phytoplankton, and terrigenous material etc. To our surprise, some of these sediments were found to contain petroleum hydrocarbons. It is possible that these originate from oil seeps but we have not yet done a detailed comparison with the material from Bruny Island. Preliminary work suggests that these samples do not contain significant amounts of the alkyl cyclohexanes found in the Bruny Island material. We still need to do further work to characterise the hydrocarbon distributions, and to establish whether these originate from pollution or from oil seeps.

It might be useful in the future to undertake a sampling program to assess how widespread these occurrence are. This would involve collecting grab samples of sediments in waters off Bruny Island and analysis for hydrocarbons by gas chromatography. Any samples that contained suspected petroleum hydrocarbons would then have to analysed by gas chromatography-mass spectrometry. The Division of Oceanography has all the necessary equipment for these analyses and I have the expertise to interpret the data. However, such analyses are not part of our main research program so they could only be undertaken on a cost-recovery basis.

I hope that this information is of use to you in relation to petroleum exploration plans for this area.

Your sincerely,

[signature]

Dr. J.K. Volkman
Senior Research Scientist
CSIRO Division Of Oceanography

copies to:
Dr. A. D. McEwan, Chief, CSIRO Division of Oceanography
Mr. B. Jackson, Divisional Secretary
Mr. M. Bendall, Director, Conga Oil Pty. Ltd.

C02
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775033

24 July 1987

F 3/0/0
F 6853/87

Conga Oil Limited
84 Wells Parade
BLACKMANS BAY TAS 7152

Attention: Mr M. Bendall

REPORT F 6853/87

YOUR REFERENCE:	Letter from D. Gravestock (SADME)
TITLE:	Maturity of five early Palaeozoic samples
LOCALITY:	TASMANIA
IDENTIFICATION:	As listed in report
DATE RECEIVED:	30 June 1987
WORK REQUIRED:	Total organic carbon. Extractable organic matter. Thin layer chromatography and methyl-phenanthrene index (MPI).

Investigation and Report by: Teresa O'Leary

Manager, Petroleum Services Section: Dr Brian G. Steveson

for Dr William G. Spencer
General Manager
Applied Sciences Group

CC. D. Gravestock (South Australian Department of Mines and Energy)

cap

1. INTRODUCTION

This report formally presents the results of geochemical analysis on five Early Palaeozoic samples.

2. ANALYTICAL METHODS

Details of analytical methods are given in Appendix 1.

3. RESULTS

Results of the analysis carried out are displayed in Tables 1 and 2. Figures 1-5 show the relative distributions of the phenanthrenes in the five samples submitted. Rock-Eval pyrolysis was not carried out due to the low organic carbon content of the samples.

4. DISCUSSION

Overall the organic richness of these samples is extremely poor (TOC = 0.02-0.23%). The low yields of extractable organic matter per gram of total organic carbon (Table 1) suggests the organic matter present is not good quality.

However, the maturity parameters obtained (Table 2) indicate that the maturity of the dispersed organic matter in these samples lies within the oil window (VR = 0.5-1.35%).

TABLE 1: ROCK EXTRACT DATA ON FIVE EARLY PALAEOZOIC SAMPLES

Sample Identification	TOC %	Wt Rock g	EOM ppm	EOM mg/g TOC
A49/122666	0.23	145.72	106	46.09
SS16	0.04	180.57	64	16.00
CI	0.02	114.83	97	48.5
IB7	0.07	201.67	22	3.15
IB112/63986	0.13	187.79	91	70.00

TABLE 2: AROMATIC MATURITY INDICATERS OF FIVE EARLY PALAEOZOIC SAMPLES

Sample Identification	MPI	MPR	DNR	VRcalc a	b	c	d	e
A49/122666	1.29	3.10	-	1.17	1.53	1.43	-	1.12
SS16	0.91	1.35	-	0.95	1.75	1.07	-	0.85
CI	0.72	1.47	-	0.83	1.87	1.11	-	0.72
IB7	0.69	1.84	-	0.81	1.89	1.20	-	0.70
IB112/63986	1.23	4.06	-	1.14	1.56	1.54	-	1.08

KEY TO AROMATIC MATURITY INDICATORS

Methylphenanthrene index (MPI), methylphenanthrene ratio (MPR), dimethylnaphthalene ratio (DNR) and calculated vitrinite reflectance (VR_{calc}) are derived from the following equations (after Radke and Welte, 1983; Radke *et al.*, 1984):

$$MPI = \frac{1.5\ (2\text{-}MP + 3\text{-}MP)}{P + 1\text{-}MP + 9\text{-}MP}$$

$$VR_{calc}\ (a) = 0.6\ MPI + 0.4\ (\text{for } VR < 1.35\%)$$

$$VR_{calc}\ (b) = -0.6\ MPI + 2.3\ (\text{for } VR > 1.35\%)$$

$$MPR = \frac{2\text{-}MP}{1\text{-}MP}$$

$$VR_{calc}\ (c) = 0.99\ \log_{10} MPR + 0.94\ (\text{for } VR = 0.5\text{–}1.7\%)$$

$$DNR = \frac{2,6\text{-}DMN + 2,7\text{-}DMN}{1,5\text{-}DMN}$$

$$VR_{calc}\ (d) = 0.046\ DNR + 0.89\ (\text{for } VR = 0.9\text{–}1.5\%)$$

Where P	=	phenanthrene
1-MP	=	1-methylphenanthrene
2-MP	=	2-methylphenanthrene
3-MP	=	3-methylphenanthrene
9-MP	=	9-methylphenanthrene
1,5-DMN	=	1,5-dimethylnaphthalene
2,6-DMN	=	2,6-dimethylnaphthalene
2,7-DMN	=	2,7-dimethylnaphthalene

Peak areas measured from m/z 155+156 (dimethylnaphthalene), m/z 178 (phenanthrene) and m/z 191+192 (methylphenanthrene) mass fragmentograms of diaromatic and triaromatic hydrocarbon fraction isolated by thin layer chromatography.

Recalibration of the methylphenanthrene index using data from a suite of Australian coals has given rise to another equation for calculated vitrinite reflectance (after Boreham and Powell, 1987):

$$VR_{calc}\ (e) = 0.7\ MPI + 0.22\ (\text{for } VR < 1.7\%)$$

FIGURES 1-5

MASS FRAGMENTOGRAMS OF AROMATIC HYDROCARBONS IN SAMPLE EXTRACTS

Fig. 1	:	A49/122666
Fig. 2	:	SS16
Fig. 3	:	CI
Fig. 4	:	IB7
Fig. 5	:	IB112/63986

m/z 178	Phenanthrene
m/z 191+192	Methylphenanthrenes

FIGURE 1

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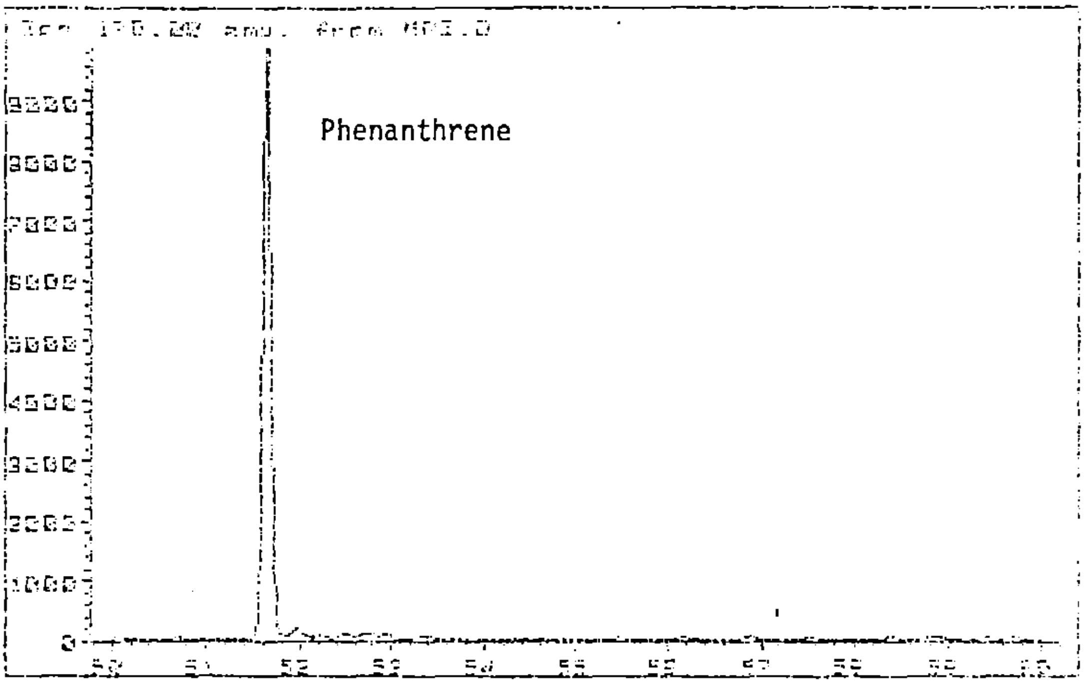

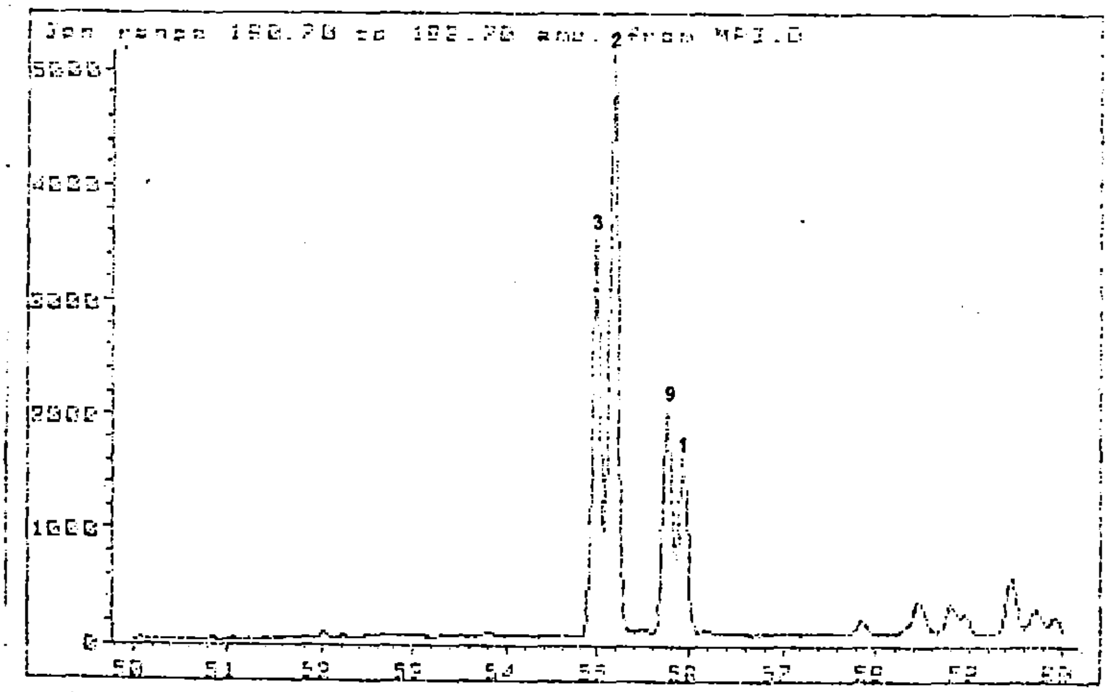

FIGURE 2

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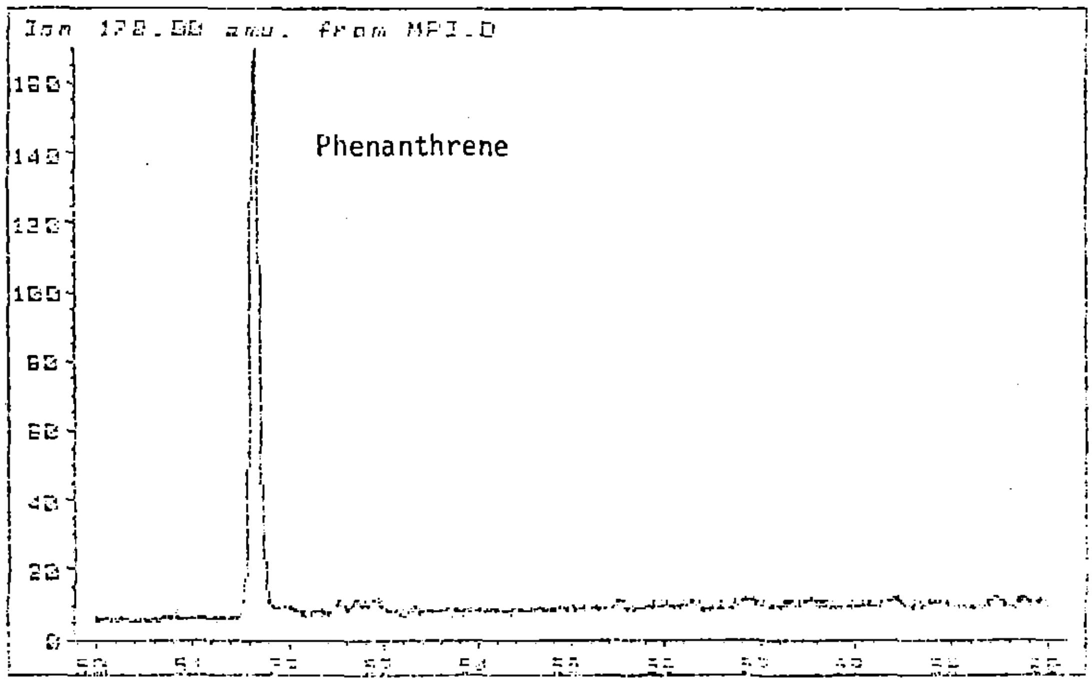

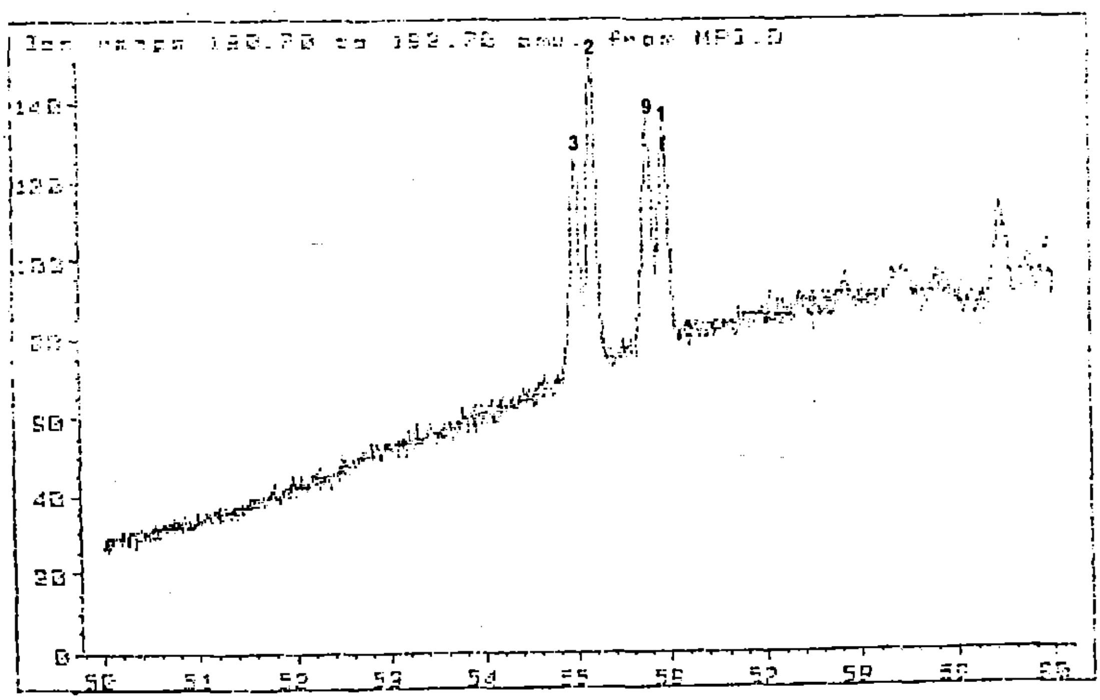

FIGURE 3

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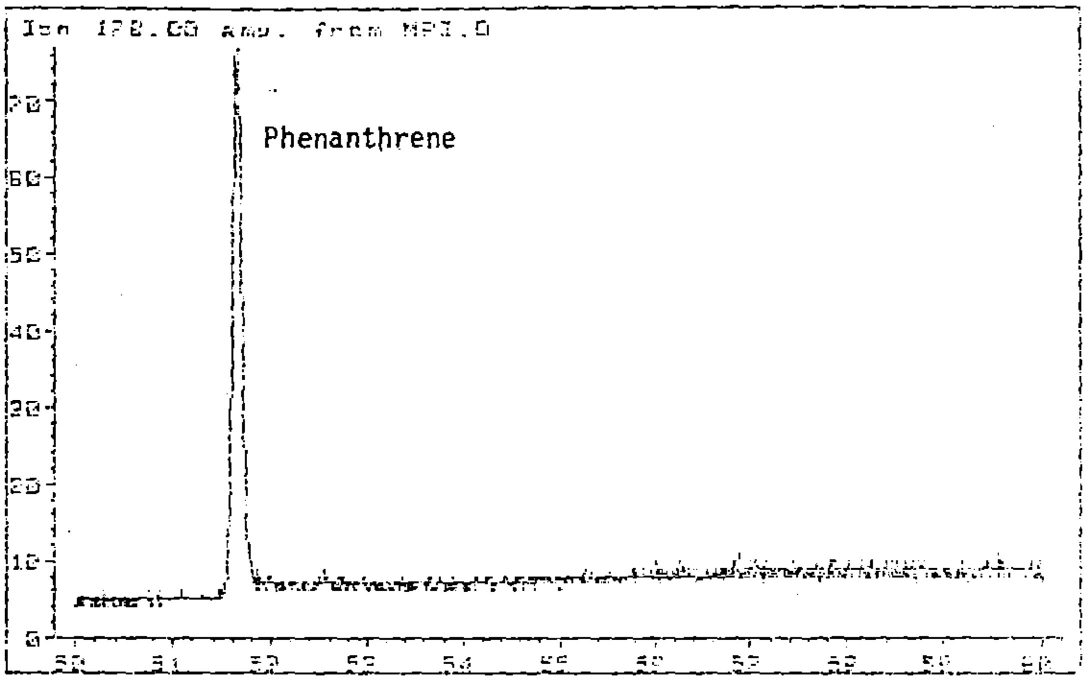

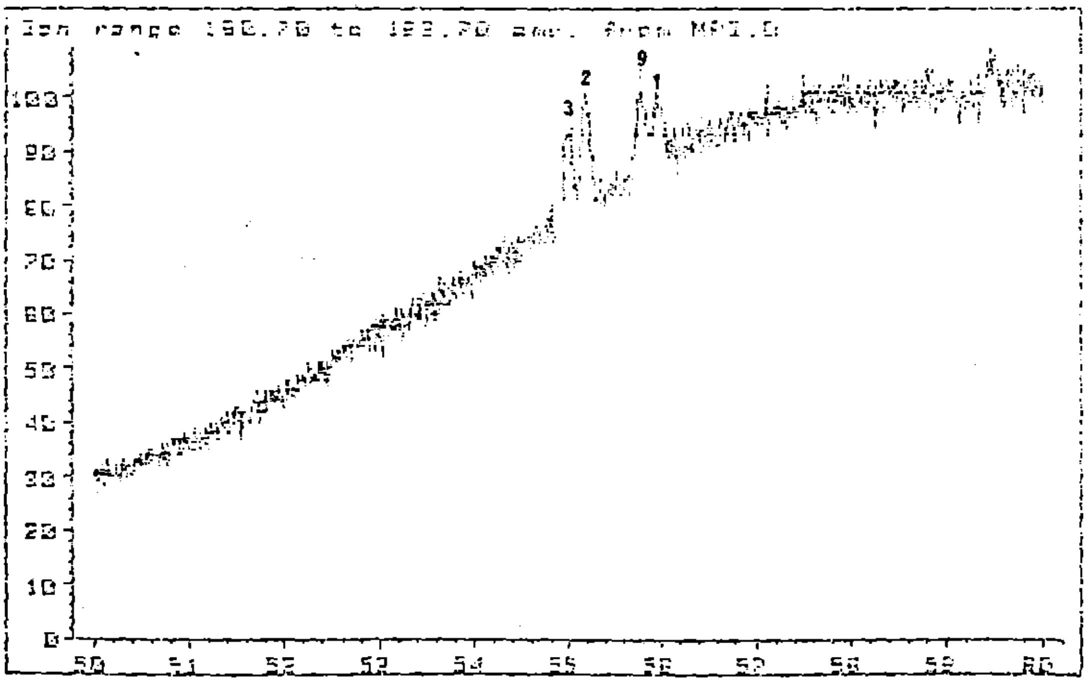

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FIGURE 4

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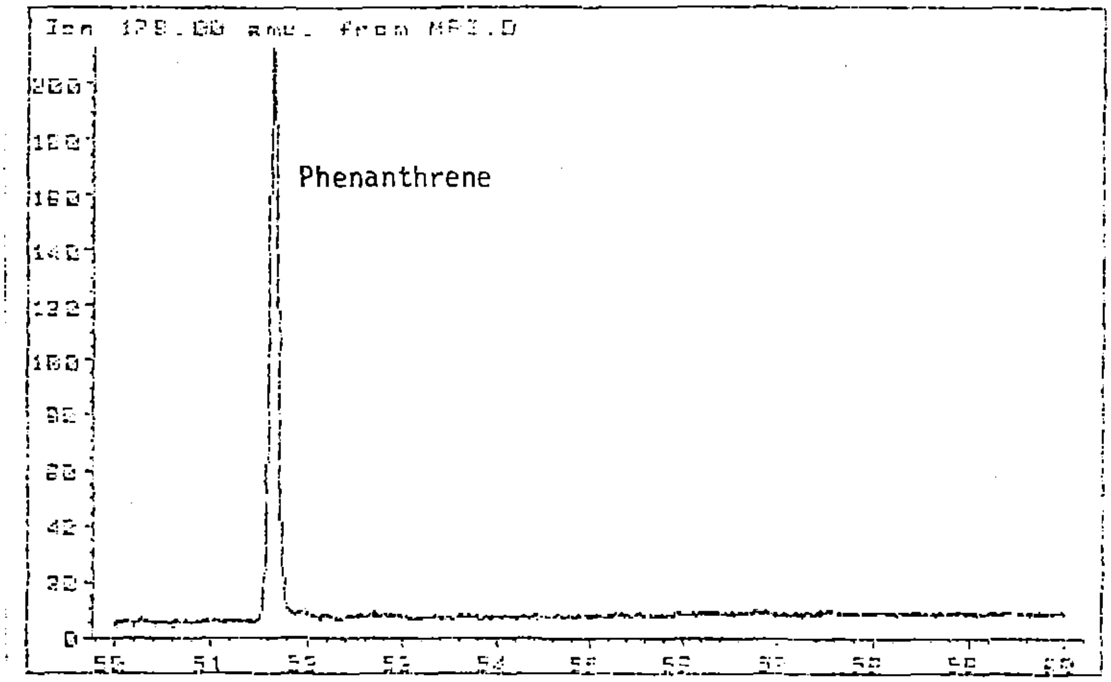

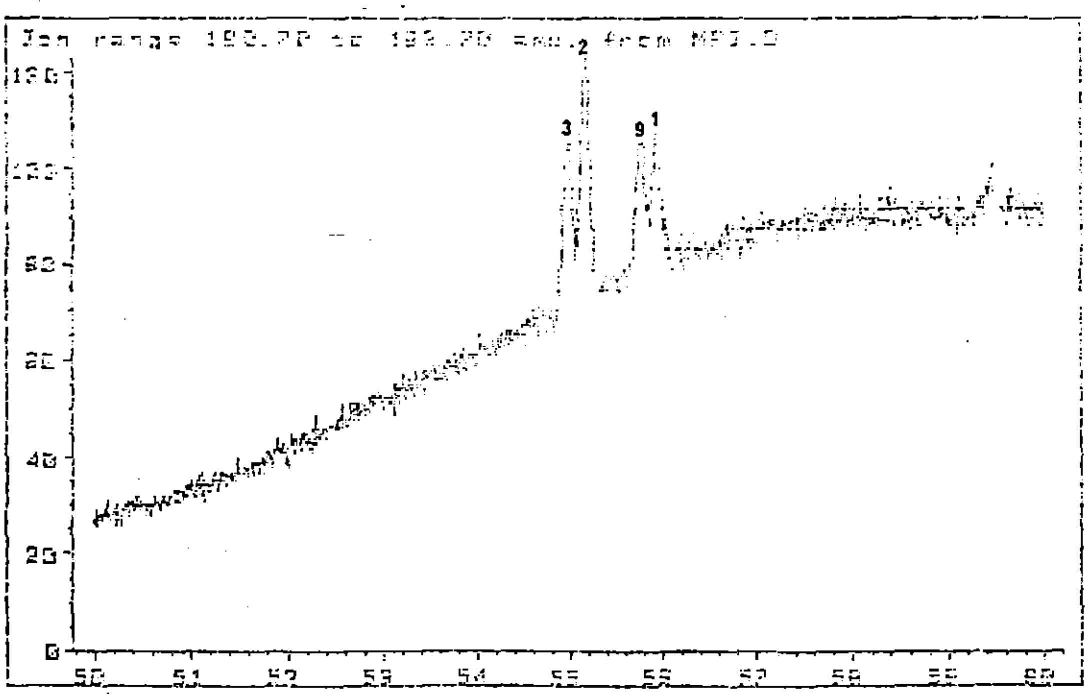

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FIGURE 5

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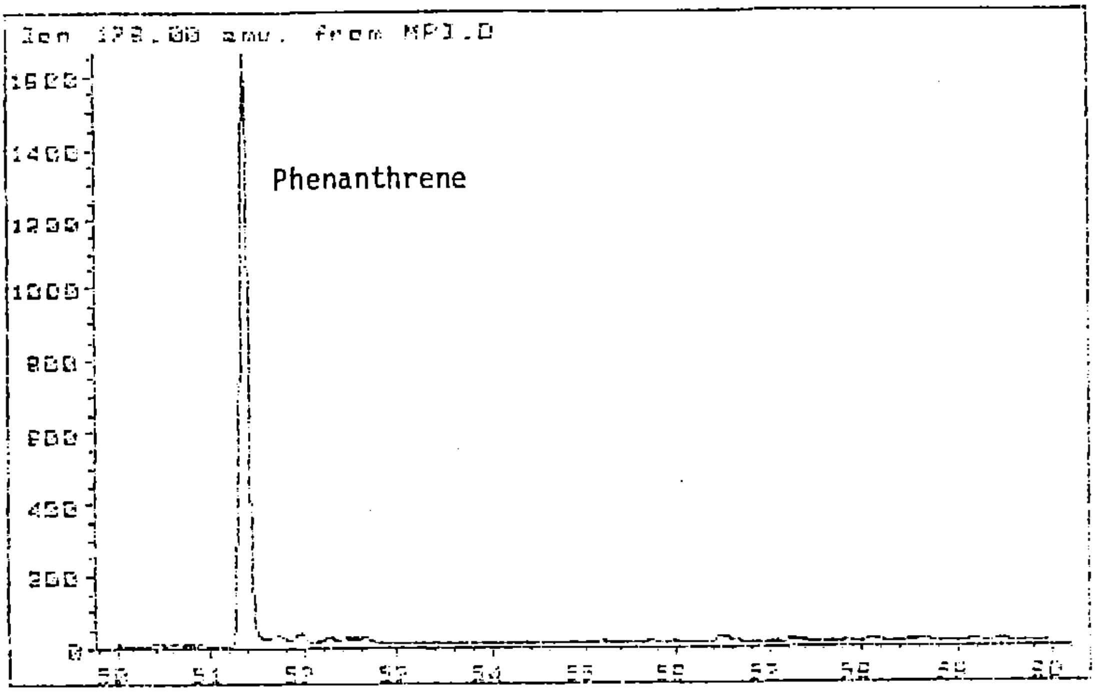
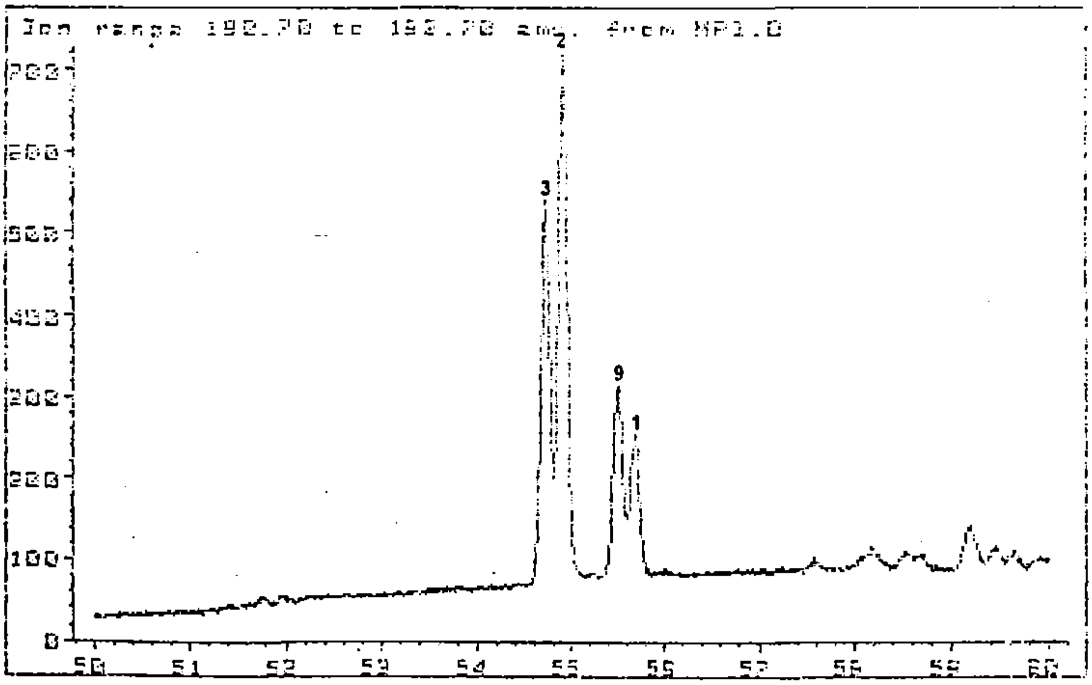




APPENDIX 1

ANALYTICAL METHODS

1. TOTAL ORGANIC CARBON (TOC)

Total organic carbon was determined by digestion of a known weight (≈0.2 g) of powdered rock in 50% HCl to remove carbonates, followed by combustion in oxygen in the induction furnace of a Leco IR-12 Carbon Determinator and measurement of the resultant CO_2 by infra-red detection.

2. EXTRACTABLE ORGANIC MATTER (EOM)

Powdered rock (100-200 g) was extracted with dichloromethane in a Soxhlet apparatus for 24 hours. Removal of solvent by careful rotary evaporation gave the EOM (nominally C_{15+}).

3. THIN LAYER CHROMATOGRAPHY (TLC)

Aromatic hydrocarbons were isolated from an aliquot of the EOM by preparative TLC using Merck GF_{254} silica plates and distilled AR grade _n_-pentane as eluent. Naphthalene and anthracene were employed as reference standards for the diaromatic and triaromatic hydrocarbons, respectively. These two bands, visualised under UV light, were scraped from the plate and the aromatic hydrocarbons redissolved in dichloromethane.

4. GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS)

The di- and triaromatic hydrocarbons isolated from the extracts by thin layer chromatography were analysed by GC-MS in the selected ion detection (SID) mode. The instrument and its parameters were as follows:

System:	Hewlett Packard (HP) 5790 GC coupled with a HP5970A mass selective detector and HP9816S data system
Column:	50 m x 0.2 mm i.d. HP PONA cross-linked methylsilicone phase fused silica, interfaced directly to source of mass spectrometer
Injector:	Split injection (40:1)
Carrier gas:	He at 1.2 kg/cm^2 head pressure
Column temperature:	50-260°C @ 4°/min
Mass spectrometer conditions:	70 eV EI; 9-ion selected ion monitoring, 70 millisec dwell time for each ion

The following mass fragmentograms were recorded:

m/z	Compound Type
178	phenanthrene
191+192	methylphenanthrenes

The area of the phenanthrene peak was multiplied by a response factor of 0.667 when calculating the methylphenanthrene index (MPI).

APPENDIX 2

MAGNETIC & GRAVITY DATA

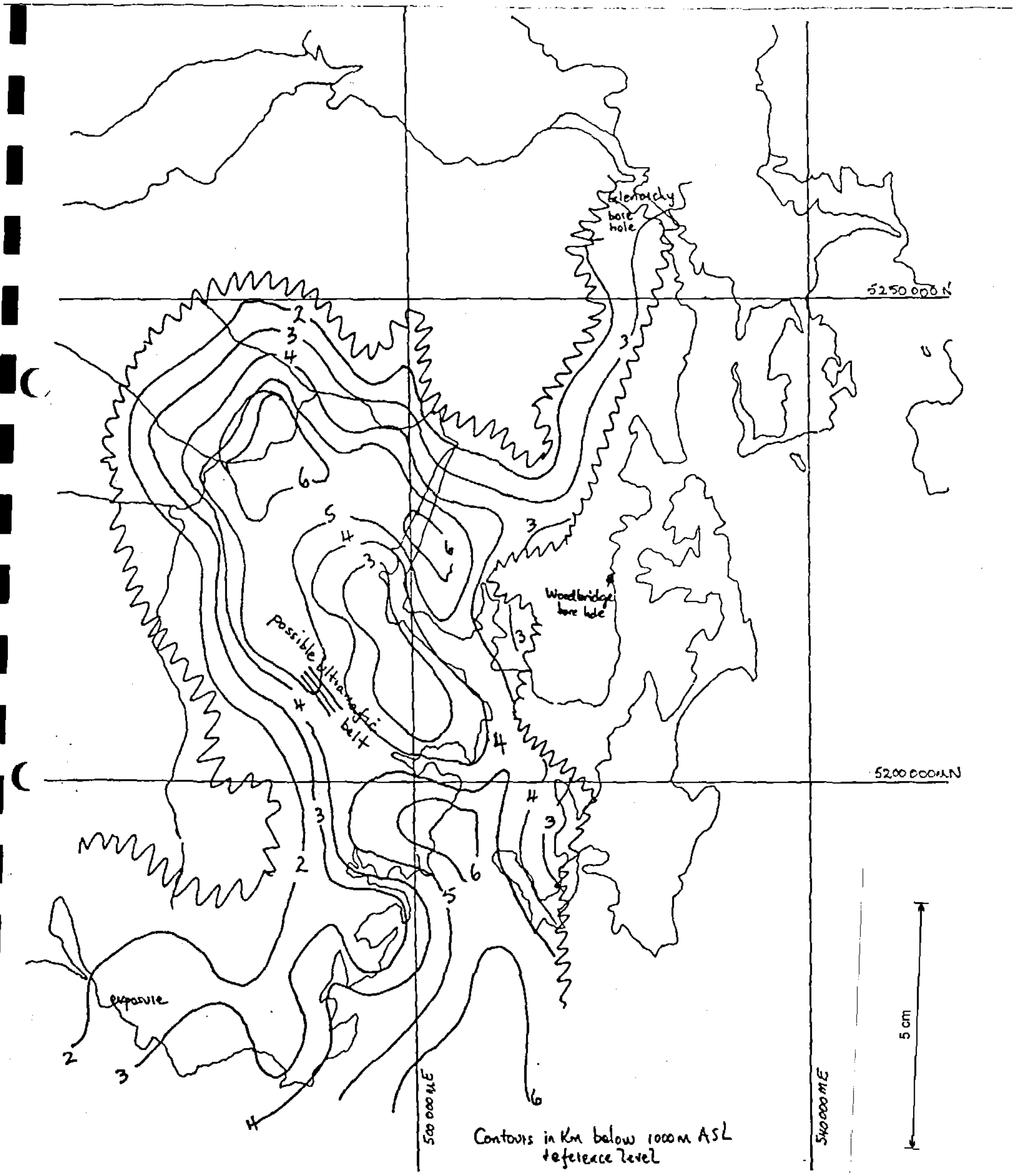
046

775047

LEAMAN GEOPHYSICS

Survey Review, Specification, Reduction, Interpretation
Wide Experience Most Methods
Specialities:- Gravity, Magnetics, Seismic Methods

Registered Office:
461 OCEANA DRIVE, HOWRAH, TAS. 7018
All Correspondence to:
G.P.O. BOX 320 D, HOBART, TAS. 7001.
TELEPHONE: (002) 47 8849



DEPTH MAP: BASE OF CAMBRIAN VOLCANIC (MAGNETIC) SEQUENCES

Derived from initial gravity-magnetic interpretation and not confirmed by 3D or second phase modelling (no control)

C47 775048

LEAMAN GEOPHYSICS

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Wide Experience Most Methods
Specialties:- Gravity, Magnetics, Seismic Methods

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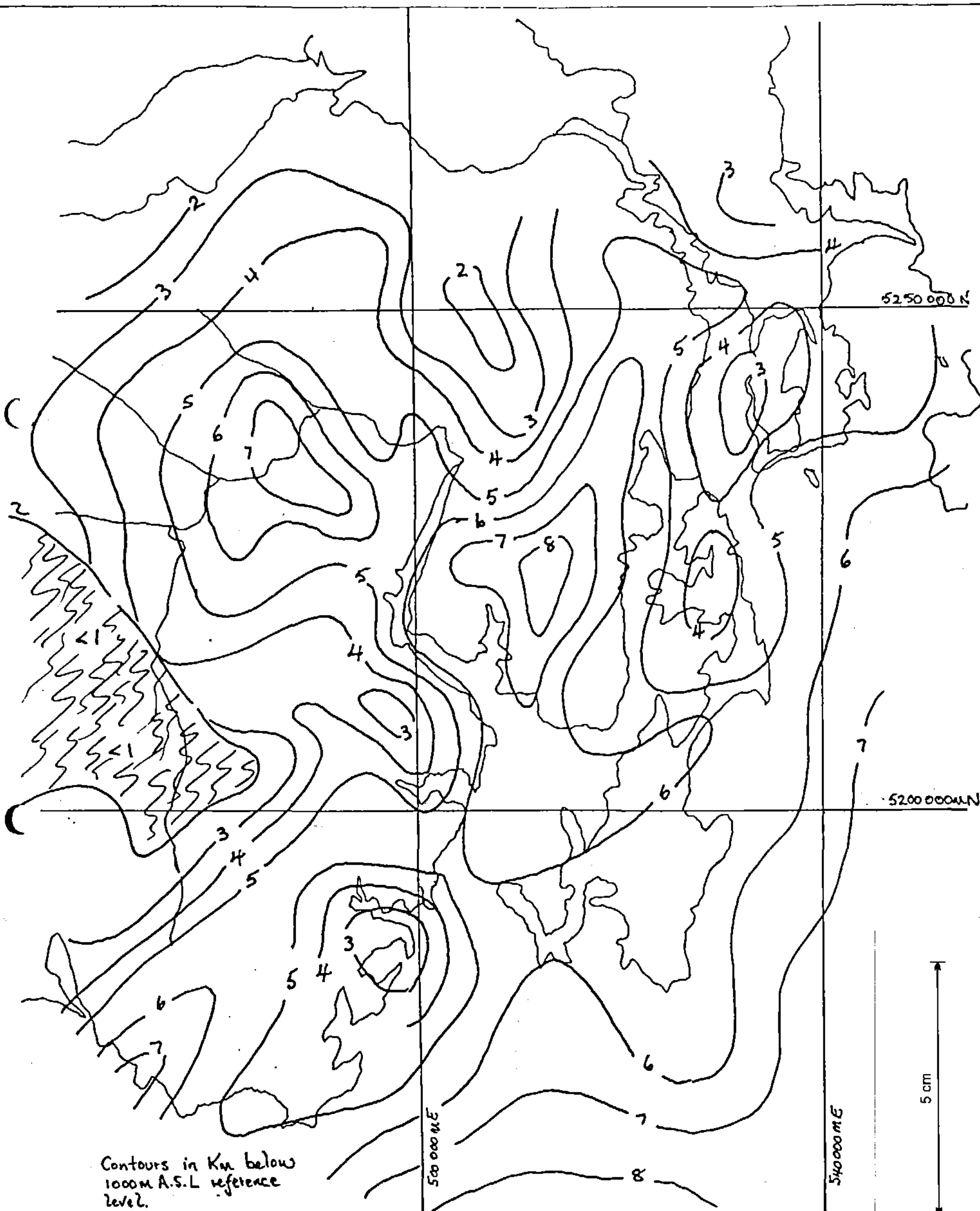
TELEPHONE: (002) 47 8849



DEPTH MAP: CRYSTALLINE BASEMENT (Tyennan Precambrian)

Derived from initial gravity-magnetic interpretation and not confirmed by 3D or second phase modelling

048

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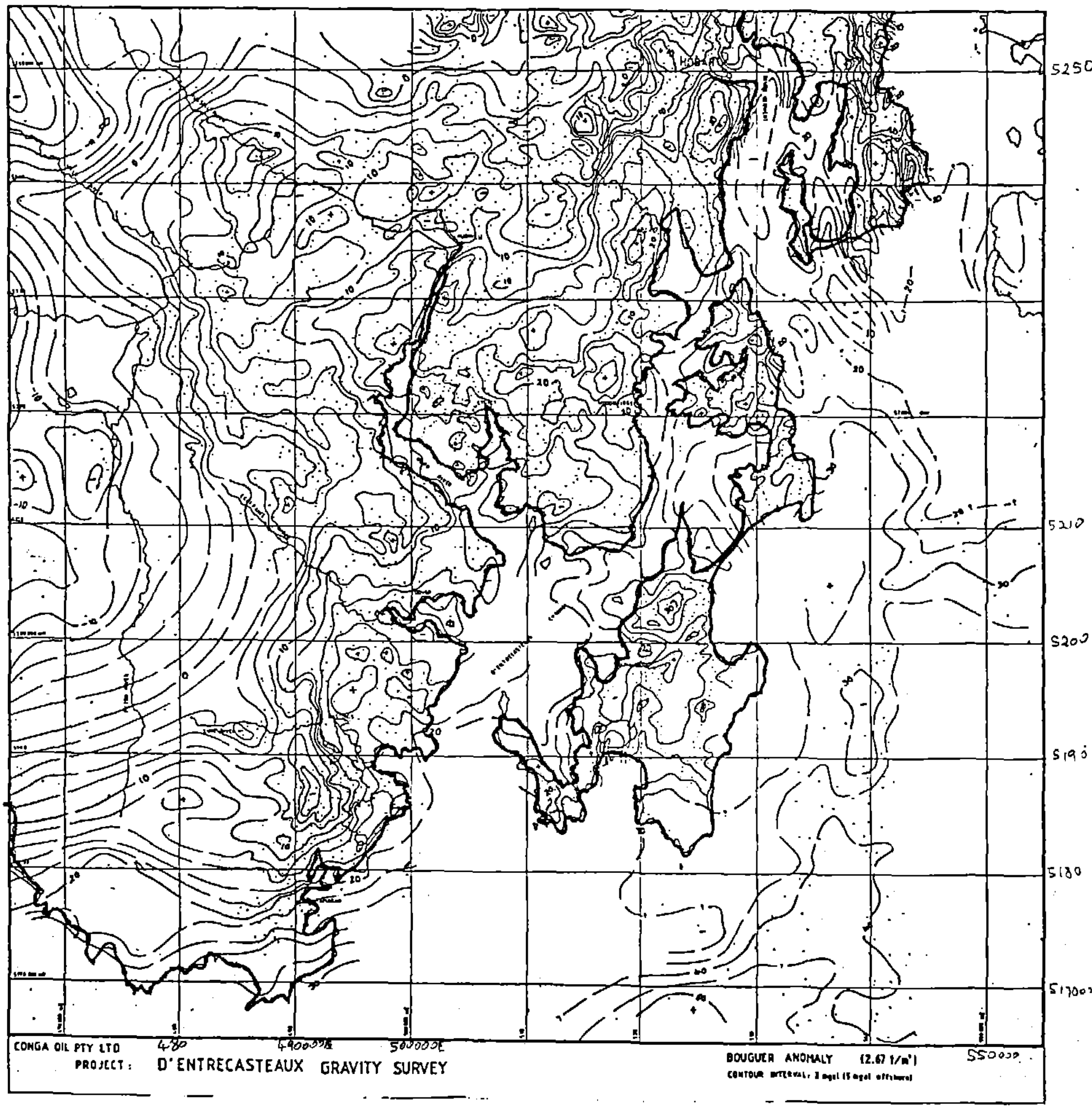

COMPILATION: D'ENTRECASTEAUX GRAVITY SURVEY (2mGal interval)
Includes data from TASGRAV data base.

FIGURE 2

5 cm

APPENDIX 2

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CONGA OIL PTY LTD

EVIDENCE FOR OIL SEEPS,

ONSHORE BRUNY ISLAND, S.E. TASMANIA

K. MORRISON
November 1987

INTRODUCTION

As part of a petroleum exploration programme currently underway in S.E. Tasmania, Conga Oil Pty Ltd conducted a search for evidence of oil seeps on Bruny Island between June and October 1987.

Bruny Island has a history of reported oil seeps and two exploration bores were sunk on the island early this century.

This report records the results to date of the Conga Oil search. The work includes: a review of previous reported seeps and previous exploration, information obtained from interviews of current and past Bruny Island residents with knowledge of possible oil seeps, collection and analysis of samples from promising sites and interpretation of geochemical results for the purpose of oil-source rock correlation.

The sample sites and sites of previous drilling are shown on the enclosed D'Entrecasteaux 1:100 000 Land Tenure Map.

HISTORY OF PETROLEUM EXPLORATION ON BRUNY ISLAND

Prior to the current work by Conga Oil, all of the serious interest in petroleum on Bruny Island occurred between 1910 and 1930. This work is summarised in two reports to the Tasmanian Government - one, a parliamentary paper in 1915 by a consultant, Dr A. Wade, and the other contained in the 1929 Annual Mines Department Report by the then Director, A. McIntosh Reid.

Circa 1910-1912 (exact date not established) an exploration bore hole (Andrews Bore) was sunk northeast of The Big Lagoon, at the southern end of North Bruny (see map). No evidence has been found for the reasons behind this location and as to whether any hydrocarbons were recovered. Remains of drill pipe, parts of the steam powered plant and the probable collar site were located in the field. An old resident, Mr Don Davis, estimates the boring lasted approximately one year before being abandoned. He had no knowledge of any hydrocarbon shows being encountered.

The enclosed log of Andrews Bore, taken from McIntosh Reid's 1929 report, shows that it reached 430 ft and a suggested stratigraphic section intersected is: 112 ft of Cainozoic sediments overlying 79 ft of weathered Permian calcareous lutites ± dropstones, shales, grits and sands overlying 239 ft of harder Permian.

BRUNY ISLAND OIL PROSPECTS

Since preparing the report the following particulars relating to the strata passed through by the bore near the Lagoon have been obtained from Mr Guy Andrew, the Company's Superintendent :-

	Feet	
Top sand and clay	43	
Quartz sand	8	
Coarse sand	11	Cainozoic
Running drift	39	
Sand and water	11	
Limestone conglomerate	27	
Brown shale	8	
Quartz sand	5	
Limestone conglomerate	4	
Very fine sand (dry)	14	
Brown clay	6	
Limestone conglomerate	3	
Limestone	12	Permian
Hard brown limestone	3	
grey limestone	54	
Hard grit	1.5	
Hard blue siliceous shale	3	
Hard limestone	3	
Hard grit	3	
Very hard limestone with alternate bands of shale	171.5	
TOTAL	430 feet	

From McIntosh Reid (1929)

In 1915, a consultant, Dr Arthur Wade, reported to the Tasmanian Government on the oil potential of Bruny Island. Wade's assessment of seep reports was that they had been observed in summer only and that none of the sitings had been made by "competent people". He was sceptical that the reported seeps were iron hydroxide or organic residues because of the apparent absence of bituminous solids, common to most oil seeps, and because of the apparent seasonality of the sightings. He predicted that Bruny Island would have low prospectivity for petroleum because of the lack of a major Tertiary section which he maintained was in contrast to the main oil producing areas of the world at that time. Wade's report gave no evidence that he had looked for seeps on Bruny Island or that he had interviewed people claiming to have seen seeps. He made no reference to Andrews Bore, despite the fact that it was sunk 3-5 years before Wade's report.

In 1929 McIntosh Reid recorded that prior to 1915, Dr Loftus Hills had examined bituminous material presented by Bruny Island residents and concluded that it was pitch rather than crude oil. Despite these two pessimistic reports a syndicate was formed to explore for oil under the direction of one A.G. Black. McIntosh Reid reviewed their results in 1929.

Five types of possible petroleum indicators had been recorded.

1) Gas bubbles on water
2) Oil seeps from rock and soil
3) Scum on the sea surface
4) Bitumen deposits in cracks in rock
5) Bitumen fragments in ploughed paddocks.

After examining the sites and considering the various reported sitings, McIntosh Reid made the following conclusions :

1) The bubbles were marsh gas.
2) The oil seeps at Johnsons Well, near Smootheys Point, Great Bay, North Island and at Miles Creek, S.E. North Island (see map) were apparently genuine. At both locations the bedrock is Permian.
3) The oil scum on the sea surface was suspected contamination from ships.
4) The bitumen in dolerite joints east of Miles Beach was considered to be flotsam from a ship wreck laden with coal tar. Analysis of this material showed that it contained "creosote" and therefore, it was derived from wood or coal.
5) The fragments observed in ploughed paddocks were resin pieces from the grass tree Xanthorea.

The most impressive site was at Johnsons Well and in 1929, a bore hole was sunk at that site by a syndicate of locals. The present owner of the property Mr Ross Denne, believed the rig was a petrol engine-driven cable tool and that the work was amateurish and plagued with mechanical problems. The collar site with steel casing of approximately three-inch diameter is still visible about thirty-five metres north of a small dam on the probable Johnsons Well site. The drilling foreman on Johnsons Bore was a Mr Calvert and his two sons, Rex and Collin, remember seeing the drilling on many occasions. They recall that the bore hole returns contained oil in water at approximately 90 feet and they recall bringing containers from their orchard to hold this oily water. Considerable effort was spent trying to case the hole but the concrete would not set and much of the casing was destroyed when boring resumed. Mr Calvert resigned after about nine months and the hole was eventually abandoned at approximately 170 feet, sometime after Calvert's resignation. It is likely that Johnsons Bore took at least a year prior to abandonment.

CURRENT WORK

Apparently no further exploration occurred until Conga Oil Pty Ltd applied for E.L. 29/84 over North Bruny in 1986. Mr Malcolm Bendall of Conga Oil collected a sample of soil/mud from the probable Johnsons Well site and had the material analysed by Analabs, Perth. Analabs detected low levels of hydrocarbon, most of which were apparently biogenic. The C29 20S/20R sterane value from the probable petrogenic fraction indicated a maturity level equivalent to Ro 0.75%, i.e. in the oil generation window.

The Analabs results were interpreted by Dr J. Volkman, organic geochemist at the C.S.I.R.O. Marine Laboratories, Hobart. In April 1987, Dr Volkman confirmed the presence of trace amounts of steranes and hopanes with a distribution typical of mature petrogenic hydrocarbons. He also noted the presence of a series of alkyl cyclohexanes, typical of some oils sourced from Ordovicial carbonates and evaporites, but stressed that insufficient data existed to characterise the source.

Following the encouragement of the initial Johnsons Well sample, several sites on Bruny Island (and one near Cygnet on the mainland) were inspected and samples were taken from those judged to be promising. Several current and past residents of Bruny Island were interviewed and an advertisement requesting information on oil seeps was inserted in the local newsletter, "The Bruny News". Several of the reported seeps inspected were clearly of inorganic or biogenic origin and a search for bitumen in dolerite joints around Cape Queen Elizabeth was unsuccessful. Eight samples were taken from the more encouraging sites and submitted to Dr J. Volkman, C.S.I.R.O. for detailed chemical analysis. The sample sites are shown on the appendixed 1:100 000 D'Entrecasteaux Map and a brief description of each sample follows.

- SP1 Scum from the surface of the dam on the probable site of Johnsons Well.
- SP2 Mud from the dam floor, as per SP1.
- C1 Scum on creek water from farm at Cradoc (near Cygnet, mainland Tasmania).
- B4 Scum from Hazell's dam, 100 metres north of Johnsons Well.
- B5 Scum on waterhole, 200 metres west of Andrews Bore site.
- B6 Scum and sediment from creek entering D'Entrecasteaux Channel at Killora, North Bruny.
- B7 Repeat of Malcolm Bendall's soil sample at Johnsons Well.
- B8 Scum and sediment from Miles Creek where it enters the sea at Miles Beach.

The results of Dr Volkman's work are reported in C.S.I.R.O. Marine Laboratories Report 87-HC2, which should be read in conjunction with this section of this report. In summary, the initial Gas Chromatography showed total hydrocarbons (biogenic + petrogenic) dominated by n-alkanes in the C15-C37 range, with no significant unresolved humps. In order to obtain evidence of any petrogenic hydrocarbons the total hydrocarbons were analysed by Gas Chromatography-Mass Spectrometry which revealed trace amounts of polycyclic biomarkers. Possible biomarkers were enriched by molecular sieving and re-analysed by Mass Spectrometry, calibrated to select M/Z groups of steranes, hopanes and isoprenoid alkanes. The Mass fragmentograms generated by this work indicated that samples SP2, B5, B6 and B8 had biomarkers with distributions typical of mature crude oil. No petroleum residues were detected in water samples C1, SP2 and B4. All samples contained relatively abundant biogenic hydrocarbons.

Interpretation of the Mass fragmentograms from the five samples with petrogenic hydrocarbon revealed several important features.

1) Sterane and hopane data suggested an oil of maturity equivalent to Ro 0.6 - 0.7%.

2) Pristane/phytane ranged from 1.1 to 1.3 except SP2 which was 0.2. If ratios slightly greater than 1.0 are taken to indicate an oxic environment (Volkman Report) this is consistent with the fact that SP2, taken from the dam floor at Johnsons Well was the only sample from an anaerobic environment.

3) The C34 isoprenoid alkane, botryococcane, a characteristic biomarker in some Otway and Bass Basin seep hydrocarbons and apparently specific to the freshwater green algae, Botryococcus braunii, was not detected in the Bruny Island samples.

4) All samples had more of the C31 22R hopane isomer than expected. The other C31-C35 hopanes had S/S+R ratios consistent with equilibrium mixtures in mature crude and the C31 anomaly was interpreted as being caused by co-elution of another compound. Dr Volkman suggested that the C30 polycyclic alkane gammacerane may be co-eluting with the C31 22R isomer. Gammacerane has been recognised in some Oligocene oils and extracts from shales in the Shengli Oilfield, China (Shi Ji-Yang et. al., 1982). At the time of writing, the suspected co-eluting compound has been shown to be additional C31 hopane with a probable high biogenic component.

5) Tricyclic alkanes are rare and therefore, the source of these oils is unlikely to be the Permian algal oil shales, which are rich in these compounds.

6) Demythylated hopanes, normally associated with the highly biodegraded residues of crude oil, were not detected.
7) C27/C29 sterane ratios range from 0.71 - 0.98 and are typical of mature oil generated from mixed marine and terrigenous organic matter. There is apparently some doubt on the validity of using C27/C29 ratios for this purpose.

DISCUSSION

The source of the Bruny Island hydrocarbon occurrences is of major concern to the Conga Oil programme and it is likely that the source is either Ordovician or Permian in age. The shallow surficial cover at the Johnsons Well site is underlain by Upper Permian Abels Bay Formation (Kingborough 1:50 000 Sheet) and it is presumably from rocks of this unit that McIntosh Reid observed oil seepage in 1929. Maturity levels of Ro 0.75% (Analabs) and 0.60 - 0.65% (C.S.I.R.O.) are elevated relative to the regional background for the Parmeener Super Group. Vitrinite reflectance values from both the Lower Permian Mersey Coal Measures equivalents and from the Upper Triassic Fingal Valley coal measures range from 0.45 - 0.55% (C. Bacon, pers. comm.). At Langloh in the Derwent Valley the local effect on maturation of Triassic coal by Jurassic dolerite intrusion is clearly demonstrated. Coal sampled within several metres of the dolerite has an Ro of 3.6% and coal 150 metres above a dolerite sill shows Ro levels of 0.6% (i.e. Ro 0.1% above regional background). If the Ro equivalent of approximately 0.7% from steranes in the Bruny Island samples is accurate and directly comparable with coal maceral measurements in reflected light, then there are three possibilities to explain the anomalously high values on Bruny Island.

1. The Permian on Bruny Island has locally been buried deeper or subject to higher heat flow than is typical for the Tasmania Basin. In this case oil could be sourced from the Permian.

2. The Permian on Bruny Island has been thermally affected by Jurassic dolerite and/or Cretaceous syenite. In this case, oil could be sourced from the Permian.

3. The mature oil has migrated up section from a pre Permian source. In this case the most likely contender is the Ordovician although Cambrian or Precambrian are possibilities. An Ro equivalent to 0.7% is similar to conodont colour indices obtained from Ordovician rocks in the Ida Bay area, Southern Tasmania by Dr C. Burrett, University of Tasmania.

In the event that sterane ratios from trace amounts of hydrocarbon are not directly comparable to vitrinite data then the oil may represent small amounts generated at sub oil window maturities. Organic-rich lutites, especially those of Mesozoic and older ages will generate trace amounts of catagenic (petrogenic) hydrocarbon when thermally immature in terms of the threshold of intense generation (Fig. 1). The near absence of tricyclic alkanes implies that if the source is Permian, it is not from the Lower Permian oil shales.

Worldwide, there appears to be some consistent characteristics of Ordovician oils which are diagnostic.

Longman and Palmer (1987) described the chemistry of fifteen Mid-Upper Ordovician oils from onshore U.S. basins and concluded that previous suggestions (e.g. Reed et. al., 1986) that most Ordovician oils were derived from prokariotic organisms (blue green algae or bacteria) were correct. They found that Ordovician oils had several diagnostic characteristics consistent with the proposed organic source.

1) Predominance of n-C15, n-C17, n-C19 in the saturated fraction with odd > even dominance in the C9-C19 range.

2) Relatively low amounts of larger n-alkanes (such as those typical of land plant- or green algae-derived Kerogens).

3) Low amounts of isoprenoid alkanes such as the chlorophyll-derived pristane and phytane.

4) Abundant C29 sterane > C27 with rearranged (diasteranes) > normal steranes.

Fig. 2 shows typical gas chromatograms and mass fragmentograms from some of these oils.

Reed et. al. (1986) and Foster et. al (1986) confirm that the predominant component in the kerogens sourcing Ordovician oils in a variety of North American, Australian and Estonian basins was a problematic unicellular organism, Gloedapsamorpha prisca. This organism is interpreted to have formed benthonic mats, on the basis of the organic-rich laminae observed in bioturbated limestones.

A difficulty in comparing known Ordovician oils with the Bruny Island samples is that the latter consist of a mixture of biogenic and petrogenic hydrocarbons and it is impossible to fully segregate components from the two sources. This is

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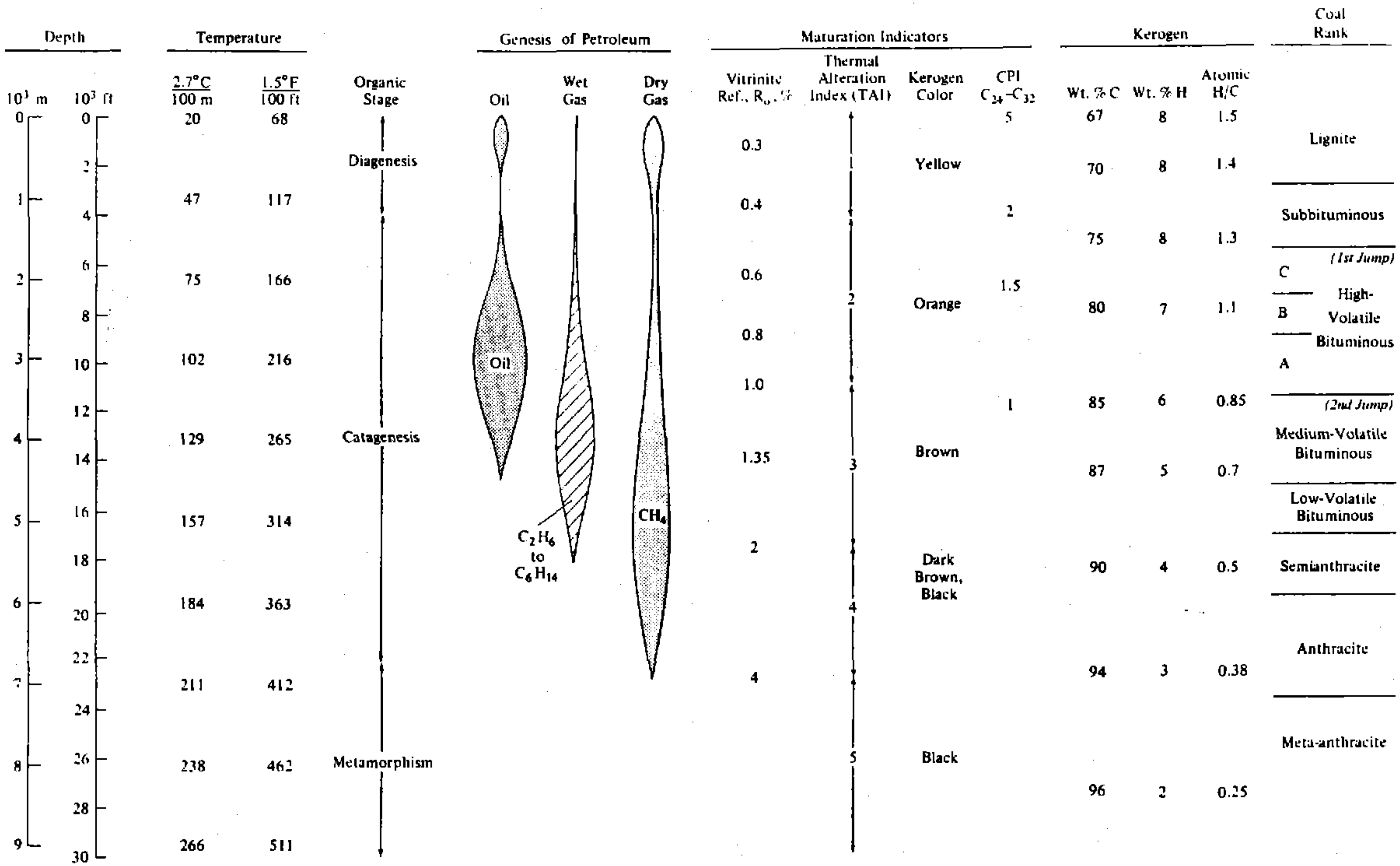
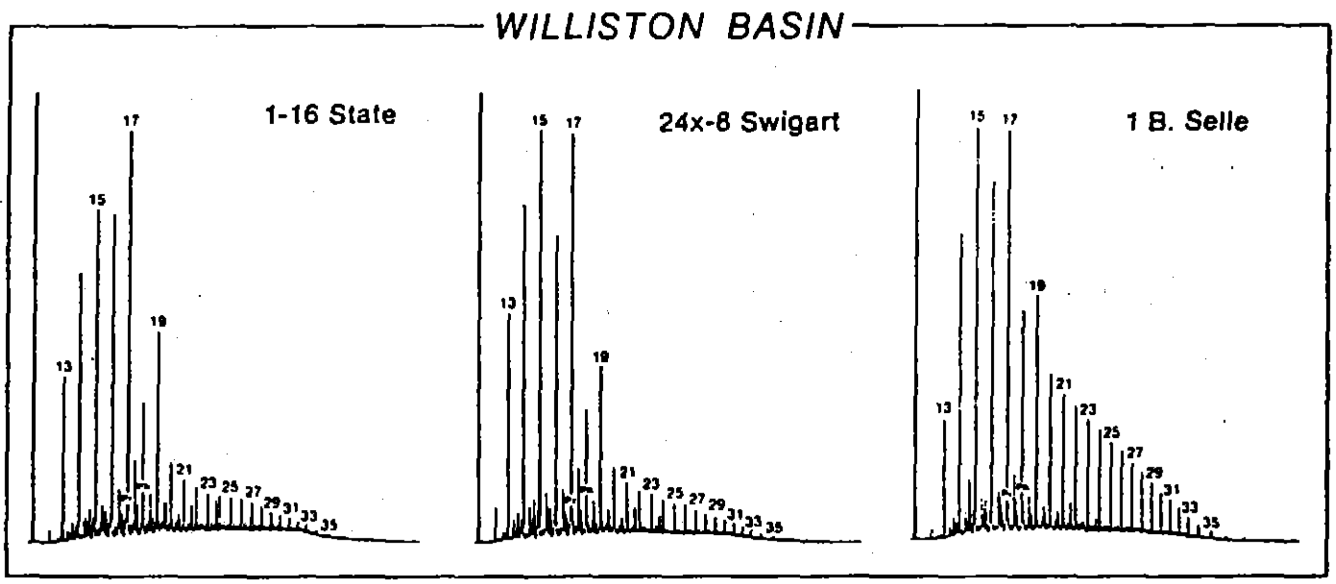
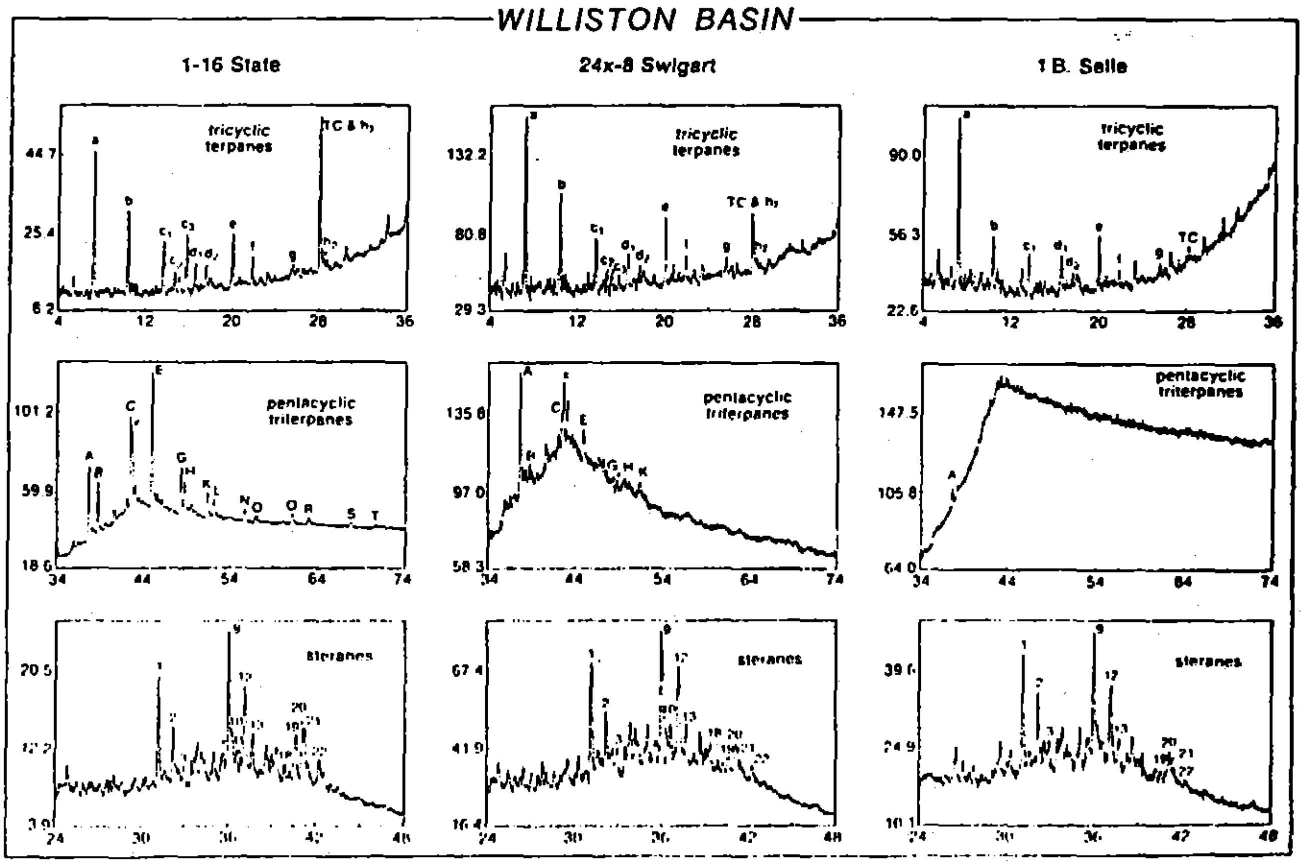


Fig. 1

Chart of organic maturation R_o = reflectance with oil immersion objective: CPI = correlation preference index. Maturation data are for an Eocene mixed-kerogen type. [Maturation limits from Dow 1977a; Staplin 1969; Teichmüller 1974] (From Hunt, 1979)



Gas Chromatograms, C15 + alkanes



Mass Chromatograms, terpanes and steranes.

Fig. 2 Williston Basin oil geochemistry (Longman & Palmer, 1987)

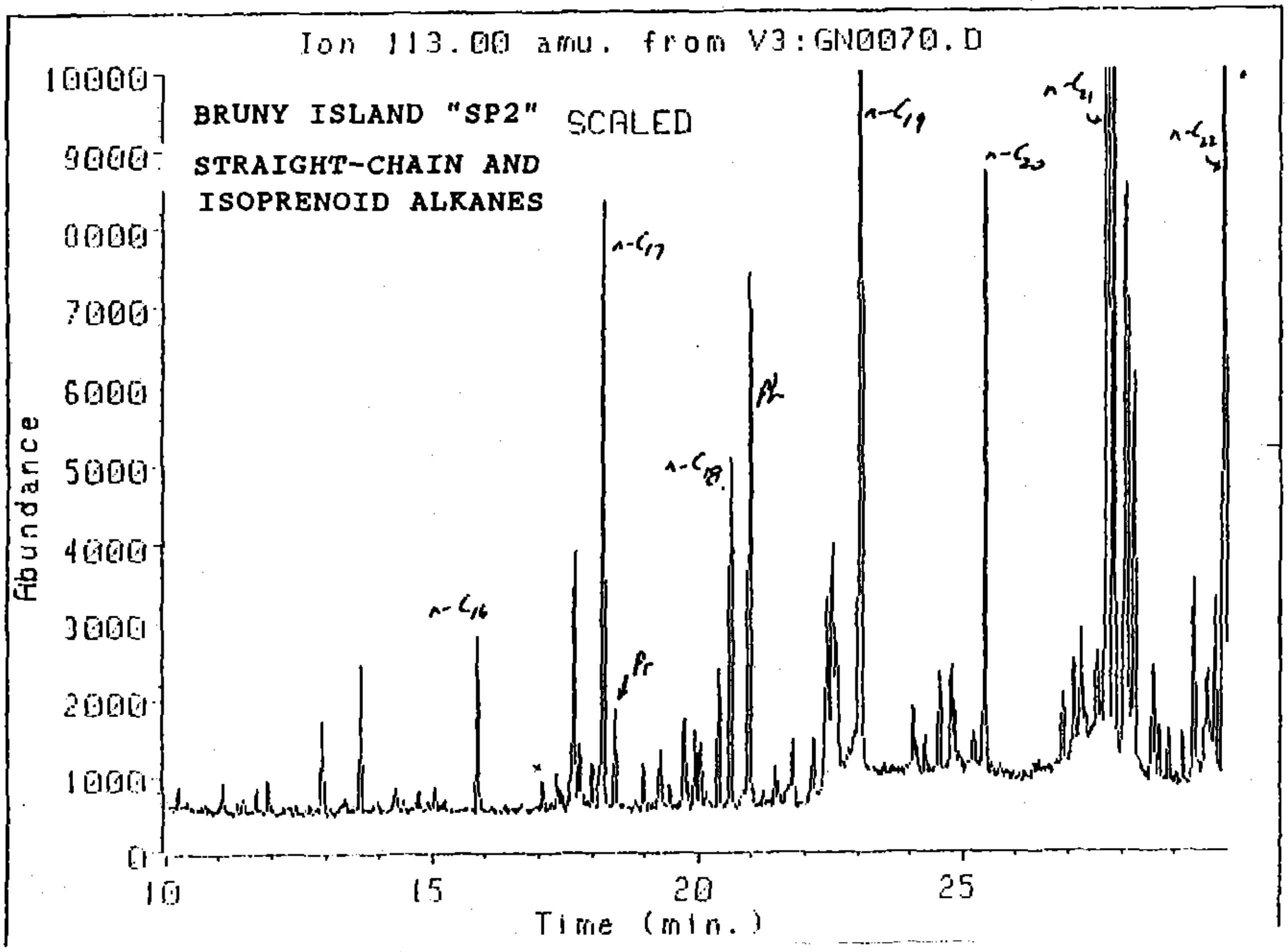


Fig. 3 Mass Fragmentogram SP2 acyclic alkanes (from Volkman, 1987)

particularly true for the n- and isoprenoid alkanes.

Taking SP2, the Johnsons Well sample, as an example, Fig. 3 shows that there is an odd > even preference, at least in the higher end of the n-C9 - n-C19 range (like Ordovician oils) but the dominant n-alkane peaks are in the +C20 range and phytane and pristane are common constituents (unlike Ordovician oils).

Normal sterane C27/C29 ratios in the Bruny Island oils show a slight C29 predominance. A strong C29 predominance was a characteristic used by Longman and Palmer (1987) to differentiate Ordovician oils from Mesozoic and Tertiary marine oils in the U.S.A. Fig. 4 shows that in SP2 there is no clear C29 normal sterane or diasterane predominance.

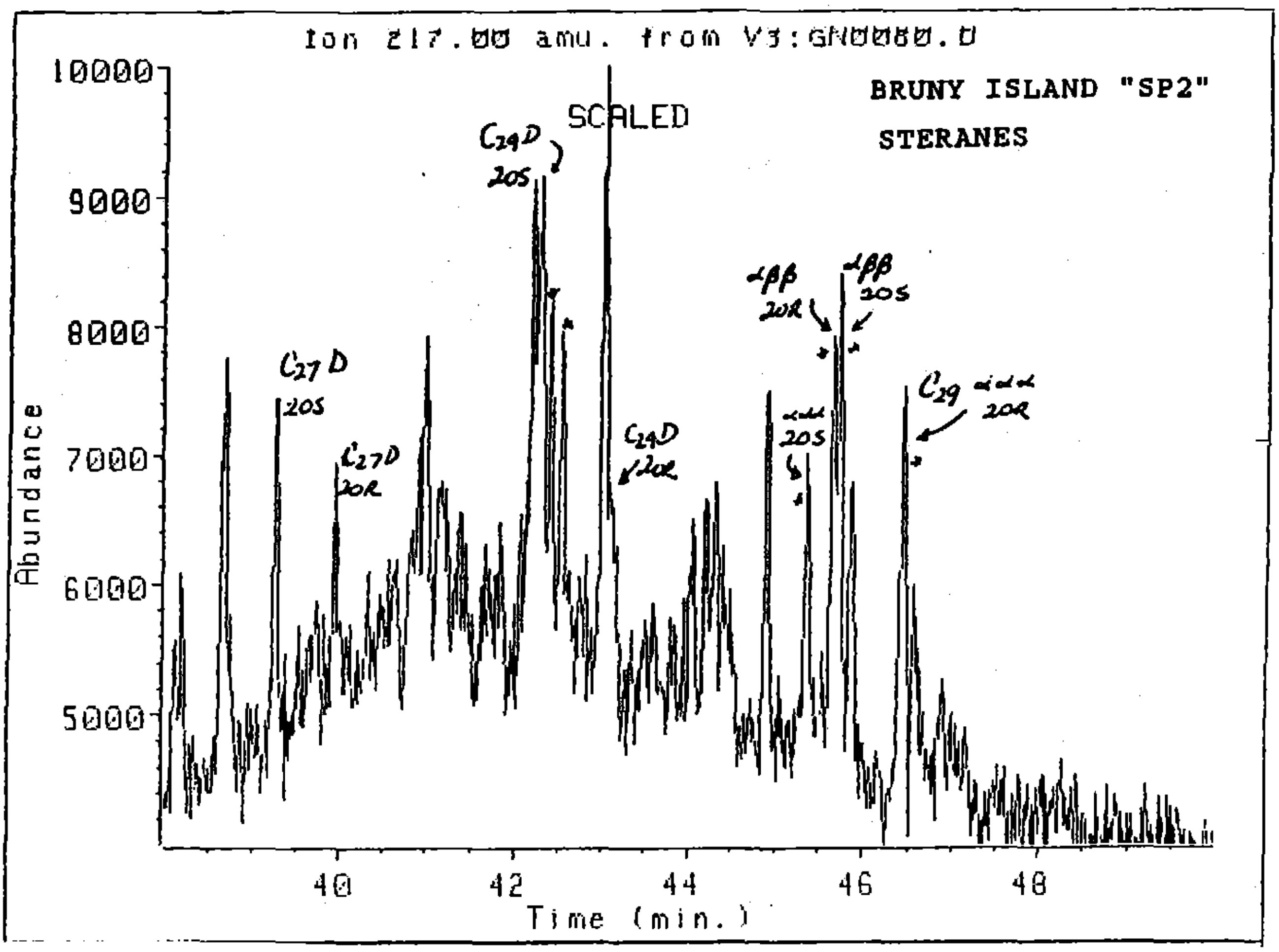


Fig. 4 Mass Fragmentogram, SP2
Steranes and diasteranes
(From Volkman, 1987)

FUTURE WORK

The Bruny Island oil seep work has not been done in isolation. A programme of seafloor sediment sampling has been conducted in D'Entrecasteaux Channel by the C.S.I.R.O., on behalf of Conga Oil, and results are currently being obtained. An aeromagnetic survey has been flown by the company and a report detailing the results of this survey, together with an interpretation of pre-existing gravity data, has been completed by Dr. D. Leaman, Hobart. Recently, a seismic reflection profile has been shot across Bruny Island and further geophysics is planned. Dr Leaman is also sampling xenoliths in Tertiary pyroclastics on Bruny Island, in an attempt to determine basement lithologies.

These data are all aimed at producing evidence for the existence of the main elements of petroleum drilling targets, i.e. source rocks, reservoir rocks, seal rocks and a trapping configuration, all appropriately juxtaposed relative to each other.

The oil seep work potentially provides useful information about reservoir rocks, seal rocks and traps on Bruny Island (or the lack of any or all of these) but its major purpose, as part of a basin study, is to provide information on the geology of the source. It may be that the drilling targets eventually defined are far removed from Bruny Island and that the real value of any seeps is that they provide samples of hydrocarbons which may occur in significant accumulations elsewhere in the basin. For this reason it is recommended that further work be done to try to correlate the Bruny Island oil samples with potential source rocks. Within budgetry allowances, samples of fresh outcrop and drill core should be taken, particularly from Ordovician and Permian lutites, in southern Tasmania and analysed by John Volkman.

CONCLUSIONS

1. Apparently genuine oil seeps were observed in Permian rocks at Johnsons Well and Miles Creek around 1929.

2. Johnsons Bore was reported to have intersected oil-stained water at approximately 90 feet depth.

3. Six samples taken from Bruny Island in 1986 and 1987 contained trace amounts of petroleum hydrocarbons. The samples cover a wide range of sites on North Bruny Island and the hydrocarbon composition shows a consistency which suggests a common source.

4. The quantities of hydrocarbons are too small to be considered as proof of oil seeps as all organic-rich rocks will yield some petroleum if the activation energy barrier of their kerogen content is exceeded by some combination of heat, time and the presence of appropriate catalysts.

5. The chemistry of the Bruny Island hydrocarbon occurrences indicates a moderately mature oil with some similarities and some dissimilarities to known Ordovician oils from other basins. The source of the oil samples remains unknown.

6. It is recommended that more geochemical work be done on the correlation of the Bruny Island hydrocarbon to possible source rocks, particularly those of Ordovician and Permian ages.

REFERENCES

Foster, C.B., O'Brien, G.W. and Watson, S.T., 1986. The APEA Journal, 1986. pp. 142-155.

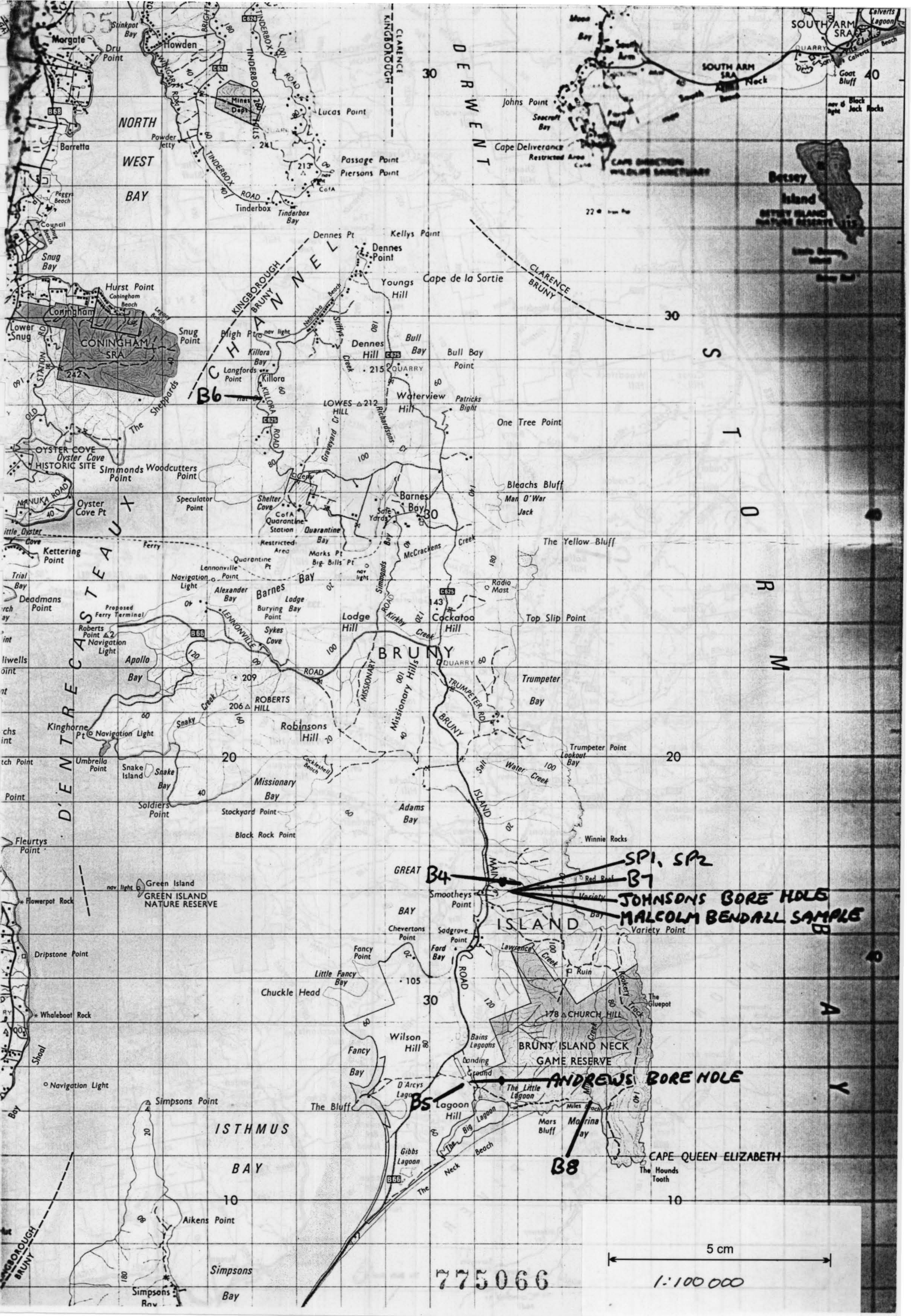
Hunt, J.M., 1979. Petroleum geochemistry and geology.

Longman, M.W. and Palmer, S.E., 1987. Organic geochemistry of Mid-Continent Middle and Late Ordovician oils. AAPG Bulletin 71, 8. pp. 938-950.

Reed, J.D. Illich, M.A. and Horsfield, B. 1985. Biochemical evolutionary significance of Ordovician oils and their soruces. Organic Geochemistry, 10. pp. 347-358.

Shi Ji-Yang, Mackenzie, A.S., Alexander, R., Eglington, G., Gowar, A.P., Wolff, G.A. and Maxwell, J.R., 1982. A biological marker investigation of petroleums and shales from the Shengli Oilfield, The Peoples Republic of China. Chemical Geology, 35. pp. 1-31.

Volkman, J.K., 1987. Analysis of sediments and water samples from Bruny Island for petroleum hydrocarbons. C.S.I.R.O. Marine Laboratories, Report 87-HC2.


NORTH
WEST
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Howden
Dru Point
Stinkpot Bay
Barretta
Snug Bay
Hurst Point
Coningham
CONINGHAM SRA
Lower Snug
Snug Point
Powder Jetty
Tinderbox
Tinderbox Bay
Passage Point
Piersons Point
Lucas Point
Dennes Pt
Dennes Point
Kellys Point
Youngs Hill
Cape de la Sortie
Bligh Pt
Killora Bay
Langfords Point
Killora
Dennes Hill
Bull Bay
Bull Bay Point
LOWES HILL
Waterview Hill
Patricks Bight
One Tree Point
OYSTER COVE
Oyster Cove
HISTORIC SITE
Simmonds Point
Woodcutters Point
Oyster Cove Pt
Speculator Point
Shelter Cove
Quarantine Station
Quarantine Bay
Barnes Bay
Bleachs Bluff
Man O'War Jack
The Yellow Bluff
Kettering Point
Deadmans Point
Navigation Light
Alexander Bay
Lennonville Point
Marks Pt
Big Bills Pt
Burying Bay Point
Radio Mast
Top Slip Point
Roberts Point
Lodge Hill
Cockatoo Hill
Sykes Cove
Apollo Bay
ROBERTS HILL
Robinsons Hill
Missionary Hills
Trumpeter Bay
Kinghorne Pt
Umbrella Point
Snake Island
Snake Bay
Soldiers Point
Missionary Bay
Stockyard Point
Black Rock Point
Adams Bay
Trumpeter Point
Winnie Rocks
Fleurtys Point
Green Island
GREEN ISLAND NATURE RESERVE
Flowerpot Rock
Dripstone Point
Whaleboat Rock
Navigation Light
Smootheys Point
Chevertons Point
Sadgrove Point
Ford Bay
Fancy Point
Little Fancy Bay
Chuckle Head
Variety Point
Red Reef
Wilson Hill
Fancy Bay
CHURCH HILL
BRUNY ISLAND NECK
GAME RESERVE
The Gluepot
The Bluff
Lagoon Hill
The Little Lagoon
Mars Bluff
CAPE QUEEN ELIZABETH
The Hounds Tooth
Gibbs Lagoon
The Big Lagoon
The Neck Beach
Simpsons Point
Aikens Point
Simpsons Bay
Johns Point
Cape Deliverance
SOUTH ARM
Betsey Island
Goat Bluff
Black Jack Rocks
KINGBOROUGH
CLARENCE
BRUNY
B6
B4
SP1, SP2
B7
JOHNSONS BORE HOLE
MALCOLM BENDALL SAMPLE
ANDREWS BORE HOLE
B5
B8
5 cm
1:100 000

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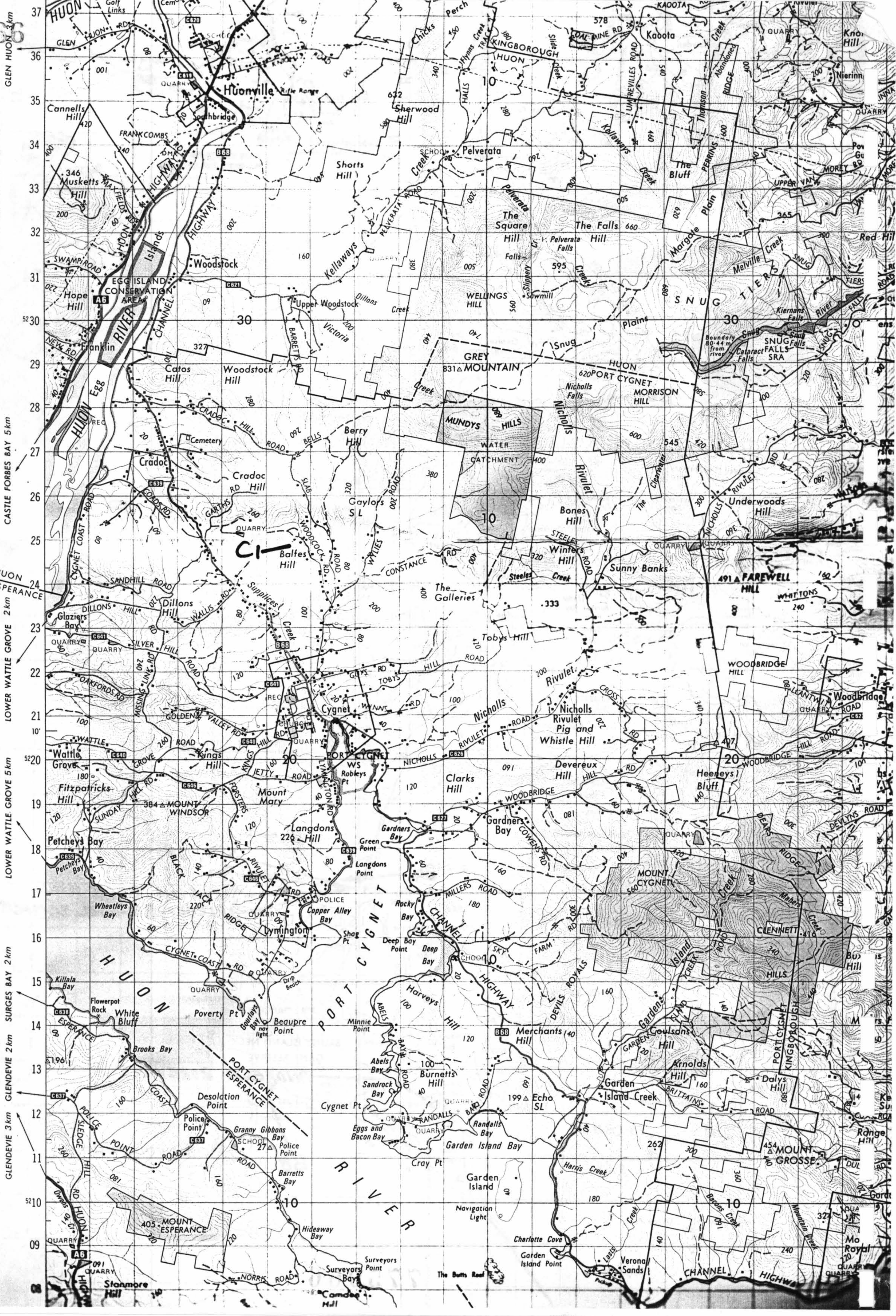

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ESPERANCE
LOWER WATTLE GROVE 2km
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GLENDEVIE 2km
GLENDEVIE 3km
Huonville
Southbridge
Rifle Range
Golf Links
Cannells Hill
Musketts Hill
Woodstock
EGG ISLAND CONSERVATION AREA
Islands
HUON RIVER
Egg
Franklin
Hope Hill
Catos Hill
Woodstock Hill
Upper Woodstock
Victoria
Kellaways
Shorts Hill
Sherwood Hill
Chicks
Perch
Pelverata
Pelverata Falls
The Square Hill
The Falls Hill
Kaoota
Kellaways Creek
The Bluff
Thomson
PERRINS
Margate
Plain
Melville Creek
SNUG TIERS
Snug Plains
WELLINGS HILL
Sawmill
GREY MOUNTAIN
HUON
PORT CYGNET
Nicholls Falls
MORRISON HILL
Kiernans Falls
Cataract Falls
SNUG FALLS SRA
Snug Falls
Boundary 80.44 m from river
MUNDYS HILLS
WATER CATCHMENT
Berry Hill
Cradoc
Cradoc Hill
Cemetery
Gaylors SL
Nicholls Rivulet
Bones Hill
Winters Hill
Sunny Banks
Underwoods Hill
FAREWELL HILL
Balfes Hill
Supplices Creek
The Galleries
Tobys Hill
Glaziers Bay
Dillons Hill
Cygnet
PORT CYGNET
WS Robleys Pt
Nicholls Rivulet Pig and Whistle Hill
Devereux Hill
Clarks Hill
Heeneys Bluff
WOODBRIDGE HILL
Woodbridge
Wattle Grove
Kings Hill
Fitzpatricks Hill
MOUNT WINDSOR
Mount Mary
Langdons Hill
Petcheys Bay
Gardners Bay
Green Point
Langdons Point
Wheatleys Bay
Copper Alley Bay
Lymington
Shag Pt
Rocky Bay
Deep Bay Point
Deep Bay
MOUNT CYGNET
CLENNETT HILLS
Killala Bay
Flowerpot Rock
White Bluff
Poverty Pt
Gourlays Bay
Beaupre Point
Minnie Point
Harveys Hill
Merchants Hill
Goulsons Hill
Arnolds Hill
Dalys Hill
Brooks Bay
Desolation Point
Police Point
Granny Gibbons Bay
Abels Bay
Sandrock Bay
Burnetts Hill
Cygnet Pt
Echo SL
Garden Island Creek
Eggs and Bacon Bay
Randalls Bay
Garden Island Bay
Cray Pt
MOUNT GROSSE
Range Hill
Barretts Bay
Garden Island
Navigation Light
Harris Creek
MOUNT ESPERANCE
Hideaway Bay
Charlotte Cove
Garden Island Point
Verona Sands
Surveyors Bay
Surveyors Point
The Butts Road
Stanmore Hill
Camden Hill
PORT CYGNET RIVER
CHANNEL HIGHWAY
HUON HIGHWAY
KINGBOROUGH
C1

APPENDIX 3

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Marine Laboratories

REPORT 87-HC2

ANALYSIS OF SEDIMENT AND WATER SAMPLES FROM BRUNY ISLAND FOR PETROLEUM HYDROCARBONS

PREPARED BY: J. K. VOLKMAN
CSIRO DIVISION OF OCEANOGRAPHY

OCTOBER 26TH., 1987.

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Division of Oceanography

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ANALYSIS OF SEDIMENT AND WATER SAMPLES FROM BRUNY ISLAND FOR PETROLEUM HYDROCARBONS

CLIENT: K. C. MORRISON Pty. Ltd.
190 Macquarie Street
Hobart
(on behalf of Conga Oil)

DATE OF REPORT: October 26th., 1987

CONTENTS

SAMPLES

Eight samples of sediment or water from various sites on Bruny Island were supplied by Mr. Ken Morrison for analysis of hydrocarbons in order to ascertain whether any contained petroleum residues. In particular, it was hoped to confirm data from an earlier analysis of hydrocarbons from Johnson's Well by ANALABS which suggested that hydrocarbons from a possible oil seep were present at that site. Samples provided were labelled C1, SP1, SP2 and 4-8. For the purposes of this report, samples numbered 4-8 are designated as B4-B8 to distinguish these from other samples being analysed at the same time. Samples SP2 and B7 were obtained from the same site as the original sample from Johnson's well.

METHODS AND RESULTS

Each sample was extracted several times with hexane to obtain a total extract. In the case of sediments, the efficiency of the extraction was enhanced by the use of an ultrasonic probe. Hexane was used rather than more polar solvents since this is quite suitable for hydrocarbons and does not extract large amounts of polar lipids. Even so, many of the sample extracts still contained large amounts of polars relative to hydrocarbons reflecting the low abundance of the latter in these samples. A portion of the extract was analysed by Iatroscan thin-layer chromatography-flame ionisation detection (Volkman et al., 1986) from which the concentration of total hydrocarbons was calculated using appropriate calibration factors. Note that these amounts include all hydrocarbons,i.e. aliphatic and aromatic as well as biogenic and petrogenic. TLC-FID chromatograms are shown in Figures 1-3.

Hydrocarbons were separated by applying an aliquot of the total extract to a column of silica gel and eluting with hexane-toluene mixtures. These were then analysed by capillary gas chromatography on a non-polar methyl silicone fused silica capillary column. Gas chromatograms of the total hydrocarbons (aliphatics plus aromatics) are shown in Figures 4-11. Major constituents in most samples were straight-chain alkanes ranging in chain-length from C_{15} to at least C_{37}. Some n-alkane distributions showed a strong predominance of odd-carbon chain lengths which is typical of the plant waxes of vascular plants. Other distributions showed little or no predominance of odd chain-lengths. Although such distributions are typical of those found in crude oils, I believe it more likely that these alkanes originate from micro-organisms in the sediment or water samples. No sample showed a significant "unresolved complex mixture" (UCM or hump) which would have been expected had there been large amounts of petroleum hydrocarbons present.

In order to confirm the presence of hydrocarbons of petroleum origin, each of the hydrocarbon fractions was analysed by capillary gas chromatography-mass spectrometry to obtain full scan electon-impact mass spectra. Preliminary analysis of these data showed that some samples contained trace amounts of polycyclic biomarkers typical of crude oils although these were very much less abundant than *n*-alkanes. In order to obtain useful data, it was necessary to separate these branched/cyclic alkanes from straight-chain compounds using molecular sieves. These branched/cyclic fractions were then reanalysed using the selected ion monitoring facility of the mass spectrometer. Data for ions m/z 217 and 218 (steranes), m/z 259 (diasteranes), m/z 191 (hopanes), m/z 177 and 205 (certain hopanes), m/z 113 and 183 (acyclic isoprenoids) and various molecular ions were acquired. Representative mass fragmentograms are shown in Figures 12-45. These analyses are stored on computer disk should other presentations of the data be required. Quantitative data for selected biomarker parameters are shown in Table 1.

CHARACTERISATION OF PETROLEUM RESIDUES

Samples SP2, B5, B6, B7 and B8 were found to contain hydrocarbon biomarkers whose distributions were typical of a mature crude oil. Petroleum residues could not be detected in samples C1, SP1 or SP4. Each of these was a water sample and thus ultra-trace levels of petroleum hydrocarbons may have been below the level of detection. Each sample, however, contained easily detectable amounts of biogenic hydrocarbons (Figures 4,5,7).

Analyses of the isoprenoid and polycyclic alkane biomarkers (Table 1) are consistent with the proposition that trace amounts of a crude oil, of moderate maturity, are present in these samples. It should be stressed that the amounts are very small and considerably lower than might have been expected if petroleum was still actively seeping at these sites. It may be that a petroleum seepage occurred some time in the past, which would account for the present-day low abundance of light-end hydrocarbons. It is not possible to rule out from the geochemical data the possibility that the petroleum hydrocarbons originated from some form of pollution by man, but it is difficult to imagine how such pollution might have occurred at the various sites.

Geochemical analyses were made difficult by the low amounts of petroleum hydrocarbons present and occurrence of biogenic polycyclic alkanes and alkenes. It was not therefore possible to carry out the usual detailed range of analyses needed to fully characterise the presumed oil. The sterane and hopane data suggest that the oil was probably generated from source rocks at a vitrinite reflectance of about 0.6-0.7. A precise estimate is not possible but it is clear that the oil was generated well into the oil window. Although there are some differences in the proportions of the various source biomarkers, at this stage the limited data suggest the presence of a similar oil at most of the sites.

(a) Acyclic isoprenoid alkanes. Pristane and phytane were detected in SP2 and B4-B8. The ratio of pristane to phytane was calculated from m/z 113 mass fragmentograms obtained from analysis of the total hydrocarbons and/or the branched cyclic fractions. Mass fragmentograms are shown in Figures 12-16. This ratio is often used as an indicator of depositional environment of the source rock. Calculated values were about 1.3 for B5-B8, and about 2.0 for B4. Values slightly greater than one are usually attributed to environments which are oxic for at least part of the time.

The pristane/phytane ratio for SP2 was much lower than the others at about 0.22. This sample contained surprisingly large amounts of phytane (Figure 12B). Such a low value is normally indicative of a highly reducing (anoxic) depositional environment. However, in environmental samples of this type it is always possible that natural sources of pristane and phytane could contribute to the hydrocarbon distributions so these interpretations need to be treated with care. It would be necessary to carry out a stereochemical analysis of both pristane and phytane to determine what proportion is derived from biogenic sources.

A search was also made for the unusual isoprenoid alkane, botryococcane, which has recently been identified as a major constituent of oil seep bitumens washed up onto South Australian beaches, but none could be detected. Amounts of sample were too small to check whether other isoprenoid alkanes are present in these samples.

(b) Pentacyclic triterpanes. Distributions of hopanes in each of the samples were quite similar. Analysis of the data was complicated in most of the samples by the presence of hopanes having an "immature" $\beta\beta$ stereochemistry (which presumably are associated with the soil organic matter) as well as unsaturated hopenes derived from baterial organic matter in the soil. The amounts of hopanes (and other biomarkers) were low in all samples and this presented a difficulty in their analysis due to a high bleed of m/z 191 from the capillary column at high temperatures. This is seen as a rising baseline in the m/z 191 mass fragmentograms.

The distributions of "geological" isomers are typical of those found in mature crude oils. Moretanes were much less abundant than 17α(H)-hopanes as expected for a mature petroleum. The C_{27} hopanes T_s and T_m were comparatively minor components of the hopane distributions which made accurate measurements of the T_s/T_m ratio difficult in some cases. In most cases, T_s was slightly less abundant than T_m which is typical of oils generated at vitrinite reflectance values less than 0.7.

One unusual feature that may be worth further investigation is the occurrence of anomolous values for the C_{31} hopane 22S/(22S + 22R) ratio. This is usually about 60% in most petroleums because these two isomers isomerise to an equilibrium mixture at maturities well before the oil window. However, all of the samples contained much more of the "C_{31} 22R" hopane than would be expected for a mature oil leading to quite anomalous ratios calculated for this maturity parameter (Table 1). This is almost certainly due to co-elution of another compound (called "X" for convenience) with the 22R isomer since the ratios for the other extended C_{31}-C_{35} hopanes are typical of a mature oil. A possible candidate is the C_{30} polycyclic alkane gammacerane which only occurs in a limited number of oils (e.g. Shi Ji-Yang et al, 1982). To confirm this identification it will be necessary to reanalyse the hydrocarbons by GC-MS using a more polar capillary column. If confirmed, this compound could be a useful marker for oil from the oil seep. A similar anomaly has been observed in the hydrocarbon distributions in sediments from the D'Entrecasteaux Channel. It is less likely than an alkene from bacteria in the sediment is coeluting because mass fragmentograms for m/z 410, the molecular ion of C_{30} hopenes, did not give a peak at this retention time.

Tricyclic alkanes are comparatively minor constituents of these samples as judged by peak areas in the m/z 191 mass fragmentograms. The source rock is thus unlikely to be associated with Tasmanites which we have found to contain large amounts of these hydrocarbons (unpublished data). The unusual hopane bisnorhopane, which occurs in the Yolla #1 oil, was not detected in any of the samples. Demethylated hopanes were not detected in any of the samples using m/z 177 mass fragmentograms. These are commonly associated with highly biodegraded residues of crude oil (Volkman et al., 1983).

(c) Steranes. Samples SP2, B5, B6 and B7 contain small amounts of C_{27} - C_{29} steranes and lesser amounts of C_{21} and C_{22} steranes. The ratios of "geological" to "biological" isomers (Table 1) is typical of a moderately mature petroleum. Maturity parameters were very similar for all of the samples but there were slight variations the source parameters (Table 1). The amount of diasteranes (rearranged steranes) was quite variable between these samples which could reflect variations in the source rock. These compounds are typically abundant where the source rocks contain large amounts of clays which catalyse the steroid backbone rearrangement. The occurrence of approximately equal amounts of C_{27} and C_{29} steranes is typical of oils generated from mixed marine and terrigenous organic matter. There is presently some debate as to the merits of this ratio for predicting the type of source organic matter, although it is still very useful as a fingerprint for comparison with potential source rocks. The ratio of the "geological" 20S $\alpha\alpha\alpha$-isomer to the "biological" 20R -isomer (Table 1) is typical of hydrocarbons generated at a vitrinite reflectance of about 0.60-0.65. 4-Methyl steranes were not abundant in any of the samples.

DETAILED DESCRIPTION OF GEOCHEMICAL DATA FOR EACH SAMPLE

Sample C1: This water sample was an algal scum from a dam at Craddock. One hundred ml of water was extracted for analysis. Hydrocarbons were very minor constituents and totalled only 30 ng/ml. A gas chromatogram of the total hydrocarbons in shown in Figure 4. Hydrocarbons consisted almost entirely of a suite of n-alkanes from C_{24} to C_{35} which showed only a slight predominance of odd-chain lengths. Short-chain alkanes were very minor components and there was no indication of a UCM. The peak for n-C_{25} is enhanced due to co-elution with a phthalate ester which is a common contaminant in environmental samples. This contaminant is not a significant component of the other samples. GC-MS analysis revealed no peaks at retention times expected for steranes or hopanes and so the sample was judged to be lacking in petroleum residues.

Sample SP1: This algal scum was obtained from a dam at Johnson's Well. One hundred ml of water was extracted with hexane for analysis. Hydrocarbons were quite minor constituents and totalled only 14 ng/ml. A gas chromatogram is shown in Figure 5. The distribution was similar to that in sample C1 and consisted mainly of a distribution of n-alkanes from C_{26} to C_{35} which showed no predominance of odd-chain n-alkanes. There was some suggestion of a UCM at low carbon numbers but no petroleum hydrocarbons could be detected by GC-MS.

Sample SP2. This was a mud sample from Johnson's Well, taken a few meters away from the original sample. One hundred grams of sediment was sieved through a 500 um mesh to remove larger pieces of plant material and then extracted with hexane using sonication to yield total hydrocarbons. The total hydrocarbon concentration was 1.7 μg/g which is fairly typical of unpolluted sediments. A gas chromatogram is shown in Figure 6. Major constituents were n-alkanes in the range from n-C_{19} to n-C_{35}. These showed a strong predominance of odd-chain lengths which is very typical of higher plants. Small peaks accompanied each of the higher molecular weight alkanes and these were identified as n-alkenes, also likely to be of higher plant origin. No obvious UCM was apparent in the gas chromatogram but analysis by GC-MS indicated that trace amounts of hydrocarbons typical of a crude oil were present in the sample.

(a) acyclic isoprenoids were minor components of the hydrocarbon extract (Figure 12). Pristane was much less abundant than n-C_{17}, but phytane was more abundant than n-C_{18} which is quite unusual. Assuming no biogenic contributions to pristane and phytane, the pristane/phytane ratio suggest a very reducing depositional environment for the presumed oil source rock.

(b) hopanes were detectable by mass fragmentogram of m/z 191, but the amounts were still quite small as evidenced by the low signal relative to column bleed. Hopanes with $\beta\beta$ stereochemistry predominated and these are unlikely to be associated with the crude oil. T_s and T_m were barely detectable. The largest peak in the m/z 191 mass fragmentogram eluted with the C_{31} 22R hopane but, as discussed previously, the main contributor to this peak is probably compound "X".

(c) steranes were detected by mass fragmentograms of m/z 217 and 218 (Figures 28 and 29). C_{27} steranes were only slightly more abundant than C_{29} steranes, with C_{28} steranes about one-third less abundant. The ratio of C_{29} sterane isomers was typical of a mature crude oil. Diasteranes were quite abundant and showed a similar ratio of C_{27}, C_{28} and C_{29} pseudo-homologues as the steranes. Several extra peaks occurred in the m/z 259 mass fragmentogram used to detect the diasteranes and the peak for the 20S-C_{29} 13β, 17α sterane was much larger than expected suggesting that an additional compound was co-eluting.

Sample B4. This was a dark brown water sample. Larger pieces of plant material were removed by sieving through a 500 μm mesh and then 250 ml was extracted with hexane. Iatroscan TLC-FID indicated that large amounts of hydrocarbons were present (720 ng/ml), but much of this consisted of carotenes, wax esters and alkenes of biogenic origin. The capillary gas chromatogram (Figure 7) revealed small quantities of n-alkanes showing a strong predominance of odd-chain lengths and no obvious UCM. Petroleum hydrocarbons could not be detected by GC-MS in SIM mode.

Sample B5. This water sample was obtained from a dam a few kilometers south of Johnson's well. Larger pieces of plant material were removed by sieving through a 500μm mesh and hydrocarbons extracted from 300 ml of water with hexane. Total hydrocarbon concentration was calculated to be 33 ng/ml from TLC-FID. A capillary gas chromatogram (Figure 8) showed a suite of n-alkanes from C_{15} to C_{37} which exhibited no predominance of odd-chain lengths. The major compound was squalene. A small UCM was present, but it was only obvious when the sample was concentrated and analysed at high sensitivities. GC-MS analysis of the total hydrocarbons in SIM mode revealed trace amounts of petroleum hydrocarbons. Hopanes were only just detectable and the amounts were not sufficient to calculate maturity parameters (Figure 19). Unlike the other samples, the ratio of C_{31} hopane 22R and 22S isomers was that expected for a crude oil, indicating that compound "X" was not present in this sample. Sterane distributions (Figures 31 and 32) were similar to those in SP2. Isomer ratios suggested a similar level of maturity and the ratio of C_{27} to C_{29} steranes was only slightly greater than in SP2. The m/z 218 mass fragmentogram contained a major additional peak that is almost certainly not a sterane. Diasteranes were slightly more abundant than in SP2 but the ratio of isomers was similar. Once again, the m/z 259 mass fragmentogram was complicated by the presence of other compounds.

Sample B6. This was a mixed water and sediment sample. Approximately 3 g of wet sediment was extracted with hexane. The concentration of total hydrocarbons was quite high at 17 $\mu g/g$ (dry weight). Analysis by capillary gas chromatography (Figure 9) showed that the major constituents were high molecular weight alkanes in a distribution that is typical of higher plants. Small amounts of n-alkenes accompanied each of the n-alkanes and these are also likely to be from higher plants. Several short chain hydrocarbons eluted between n-C_{17} and n-C_{20} and these are thought to be from natural sources. There was no obvious sign of a UCM but analysis by GC-MS in SIM mode revealed that petroleum hydrocarbons were present in trace amounts. A portion of the total hydrocarbons was separated by molecular sieves into a branched/cyclic fraction which was analysed by GC-MS in SIM mode.

(a) isoprenoid alkanes were detected from m/z 113 mass fragmentograms (Figure 16A). Pristane was slightly more abundant than phytane, but both were very much less abundant than n-alkanes.

(b) hopanes were readily detected from m/z 191, 177 and 205 mass fragmentograms (Figures 21 and 22) and their distribution was very similar to that found in SP2 with the one exception that compound "X" was not abundant. Maturity parameters were typical of a mature crude oil.

(c) steranes were readily detected by m/z 217 and 218 mass fragmentograms (Figures 34 and 35), but these also contained major peaks attributable to other compounds. The ratio of sterane isomers was typical of a mature crude oil, although values of maturity parameters (Table 1) suggested a slightly lower maturity than that found in SP2. C_{27} sterane were also less abundant than in SP2. Diasteranes were also less abundant suggesting that this oil was not identical with that found in SP2. The mass fragmentograms obtained for m/z 217 and 218 over the wider time window (Figure 35) showed major interferences from other compounds that were not steranes.

Sample B7. This sample was a dry sediment obtained from the same place as the original sample from Johnson's Well. Larger pieces of plant material were removed by sieving through a 500um mesh. Approximately 40 g of dry sediment was extracted with hexane to give total hydrocarbons. The total amount of hydrocarbons was determined to be 400 ng/g from TLC-FID. The distribution of hydrocarbons was similar to that in B6 with n-alkanes of higher plant origin predominating. Short-chain hydrocarbons were less abundant and there was no indication of a UCM. Branched and cyclic hydrocarbons were obtained by treatment with molecular sieves and analysed by GC-MS in SIM mode.

(a) isoprenoid alkanes consisted mainly of pristane and phytane (Figure 14), with pristane more abundant than phytane (Table 1). In the Analabs analysis, the abundance of pristane was even higher, but this could be due to a contribution from biogenic pristane.

(b) hopanes were readily detected from m/z 191, 177 and 205 mass fragmentograms (Figures 23 and 24) and showed a distibution of immature and mature isomers very similar to that found in the Analabs analysis. The only significant difference was a higher abundance of compound "X" coeluting with the 22R C_{31} hopane, and higher amounts of the C_{31} *BB* isomer. T_m/T_s and hopane/moretane ratios were typical of a mature crude oil. The C_{32} extended hopanes were not apparent in the ANALABS analysis but for our data their ratio is that expected for a mature oil, clearly showing that the C_{31} hopane ratio is anomalous.

(c) steranes were detected from m/z 217 and 218 mass fragmentograms (Figures 37 and 38) and their distribution was quite similar to that found in the Analabs analysis. The latter reported high concentrations of C_{27} 20R and 20S $\alpha\alpha\alpha$-steranes, but it seems from our analysis that this is due to coelution with other compounds. C_{27} steranes were slightly less abundant than C_{29} steranes and matched fairly well the distributions in B6 and SP2. Diasteranes were slightly more abundant than in the other samples but the proportion of C_{29} pseudo-homologues was greater (Table 1). Note that peak area of the C_{29} 20S diasterane is greater than expected (Figure 39), as seen in some of the other samples, presumably due to co-elution with another compound. Isomer ratios were typical of a mature crude oil.

Sample B8. This sample consisted of roughly equal amounts of sediment and water. Approximately 40 g of sediment was extracted with hexane. The concentration of total hydrocarbons was determined to be 300 ng/g from TLC-FID. Hydrocarbons consisted of a suite of n-alkanes from n-C_{19} to n-C_{37} which showed only a slight predominance of odd-chain lengths. High amounts of squalene and shorter-chain hydrocarbons of biogenic origin were also present. No obvious UCM was evident. Branched and cyclic alkanes were isolated by molecular sieves and analysed by GC-MS in SIM mode which showed that small amounts of petroleum hydrocarbons were present.

(a) isoprenoid alkanes consisted mainly of pristane and phytane with pristane slightly more abundant (Figure 15).

(b) hopanes were readily detected from m/z 191, 177 and 205 mass fragmentograms (Figure 25) and showed a similar distribution to that found in SP2 and B7. Compound "X" was abundant, but amounts of immature *BB* isomers was much less than in the other samples. Maturity ratios were typical of a mature crude oil.

(c) steranes were detected from m/z 217 and 218 mass fragmentograms (Figures 40 and 41). C_{29} steranes were slightly more abundant than C_{27} steranes, but maturity parameters were similar to those in the other samples, with the exception thet the abundance of the C_{29} 20R sterane was slightly higher than expected considering the abundance of the 20S isomer. Diasterane distributions showed a lower abundance of C_{27} pseudo-homologues than in the other samples.

REFERENCES

Shi Ji-Yang, A. S. Mackenzie, R. Alexander, G. Eglinton, A. P. Gowar, G. A. Wolff and J. R. Maxwell (1982). A biological marker investigation of petroleums and shales from the Shengli oilfield, the People's Republic of China. *Chem. Geol.* 35, 1-31.

Volkman J. K., R. Alexander, R. I. Kagi, and G. W. Woodhouse (1983). Demethylated hopanes in crude oils and their applications in petroleum geochemistry. *Geochim. Cosmochim. Acta.* 47, 785-794.

Volkman, J.K., D. A. Everitt and D. I. Allen (1986) Some analyses of lipid classes in marine organisms, sediments and seawater using thin-layer chromatography-flame ionisation detection. *J. Chromatogr.* 356, 147-162.

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TABLE 1

SELECTED BIOMARKER PARAMETERS FROM GC-MS ANALYSIS

SAMPLES: Sediment and water samples from Bruny Island supplied by Mr. K. C. Morrison.

MATURITY PARAMETERS	SP2	B5	B6	B7	B8
1. C_{27} hopanes: T_s/T_m	0.63	nd	0.70	0.38	0.79
2. C_{30} hopane/C_{30} moretane	4.8	nd	7.4	3.1	6.0
3. C_{31} 22S hopane/(C_{31} 22R + 22S hopanes) X 100	6%	nd	37%	21%	28%
4. C_{32} 22S hopane/(C_{32} 22R + 22S hopanes) X 100	56%	nd	58%	55%	60%
5. C_{29} $\alpha\alpha\alpha$-steranes: 20S/20R	0.81	0.79	0.71	0.72	0.73
6. C_{29} 20R steranes: $\alpha\beta\beta/\alpha\alpha\alpha$.	1.02	0.95	0.94	0.90	0.82
SOURCE PARAMETERS					
7. C_{27}/C_{29} steranes	0.93	0.71	0.78	0.98	0.73
8. C_{27}/C_{29} diasteranes	1.7	1.5	nd	1.0	0.77
9. Pristane/phytane	0.20	1.3	1.3	1.1	1.3

Parameters 1-4 calculated from m/z 191 mass fragmentograms
Parameters 5-7 calculated from m/z 217 and 218 mass fragmentograms
Parameter 8 calculated from m/z 259 mass fragmentograms
Parameter 9 calculated from m/z 113 mass fragmentograms.
nd: not dteremined due to co-elution with other compounds or too weak.

LIST OF FIGURES

FIGURE 15B. ISOPRENOID ALKANES FROM BRANCHED/CYCLIC ALKANE FRACTION FROM BRUNY ISLAND SAMPLE "B8".

FIGURE 16A. STRAIGHT-CHAIN AND ISOPRENOID ALKANES FROM TOTAL HYDROCARBONS FROM BRUNY ISLAND SAMPLE "B6"

FIGURE 16B. ISOPRENOID ALKANES FROM REFERENCE OIL SAMPLE WINDALIA OIL.

FIGURE 17. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES PLUS OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "SP2".

FIGURE 18A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES AND ALSO DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "SP2".

FIGURE 18B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "SP2".

FIGURE 19. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES AND OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B5".

FIGURE 20A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B5".

FIGURE 20B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "B5".

FIGURE 21. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES AND OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B6".

FIGURE 22A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B6".

FIGURE 22B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "B6".

FIGURE 23. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES PLUS OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B7".

FIGURE 24A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B7".

FIGURE 24B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "B7".

FIGURE 25. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES PLUS OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B8".

FIGURE 25A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B8".

FIGURE 25B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "B8".

FIGURE 43. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{27} - C_{30} STERANES) IN REFERENCE SAMPLE WINDALIA OIL.

FIGURE 44. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{20} - C_{30} STERANES) IN REFERENCE SAMPLE WINDALIA OIL.

FIGURE 45. MASS FRAGMENTOGRAM FOR M/Z 259 (DIASTERANES) IN REFERENCE SAMPLE WINDALIA OIL.

NOTES ON FIGURES

FIGURES 1-3. Iatroscan TLC-FID chromatograms give an indication of what lipid classes are in a sample and also their concentrations. The area under the peak is converted to a concentration value using calibration factors determined in earlier work (Volkman et al., 1986). The abbreviations are: POLARS: polar lipids, ST: sterols, HC: hydrocarbons. "Hydrocarbons" includes some contribution from wax esters and pigments such as β-carotene. Total hydrocarbon concentrations are quite low in all samples.

FIGURES 4-11. These figures are capillary gas chromatograms obtained for hydrocarbon fractions that had been purified from other lipids by silic gel chromatography. Each peak represents a different compound (in a few cases two or more compounds may elute at the same retention time), and the area under the peak is directly proportional to the amount of that compound. Alkanes are given by n-C_x where "x" is the number of carbon atoms.

FIGURES 12-16. These show mass fragmentograms for m/z 113 obtained by GC-MS analysis of either the total hydrocarbons or branched/cyclic hydrocarbons that had been purified using molecular sieves. This ion is enhanced in the mass spectra of isoprenoid alkanes and thus enables the distribution of isoprenoid alkanes to be seen clearly in complex mixtures. This ion is also found in straight-chain alkanes and so n-alkanes also appear in these mass fragmentograms. Abbreviations are: Pr: pristane, Ph: phytane, TMTD: C_{16} isoprenoid alkane.

FIGURES 17-27. These show mass fragmentograms for m/z 199, 177 and 205 obtained by GC-MS analysis of the total hydrocarbons or branched/cyclic fraction as indicated. All regular hopanes give very intense m/z 191 in their mass spectra so this ion is typically used to characterise hopanes distributions. C_{29} hopanes also have a major fragment ion at m/z 177 and so are readily detected using this ion. Hopanes which lack at C-10 methyl group (called demethylated hopanes) also give a strong ion at m/z 177 as seen in the mass fragmentograms for the Windalia oil reference sample. C_{31} hopanes give a strong ion at m/z 205 and thus are readily distinguished by this ion. Note that the ratio of C_{31} 22R and 22S isomers is anomalous in the m/z 205 mass fragmentogram as well as in the m/z 191 mass fragmentogram.

Mass fragmentograms for m/z 191 are given for two different time windows to make the distribution of C_{27} - C_{31} hopanes clearer. Note the high level of m/z 191 contributed by the column bleed. Normally this is insignificant relative to the amount of hopanes (e.g. Windalia sample) but not in this case because of the very low amounts of hopanes present.

The abbreviations used are: T_s: C_{27} hopane 18α(H)-22,29,30-trisnorneohopane, T_m: C_{27} sterane 17α(H)-22,29,30-trisnorhopane, C_xH: 17α(H)-hopane of carbon number "x", C_xM: 17β(H),21α(H)-moretane of carbon number "x", $C_x\beta\beta$: hopanes of carbon number "x" having 17β(H),21β(H)-stereochemistry (immature isomers), "X": an unknown triterpane which might be gammacerane. In extended hopanes (i.e. carbon numbers $>C_{30}$), two isomers called R and S can occur at position C-22 in the sidechain. The ratio of these two isomers changes in a systematic way with increasing maturity.

FIGURES 28-45. These show mass fragmentograms for m/z 217 and 218 over two different time windows. These ions are characteristic of regular steranes, but interferences can occur due to the presence of certain hopenes and other compounds. The ion m/z 218 is enhanced in isomers with αβ,β-stereochemistry, and so it is useful for identifying these compounds. Diasteranes (steranes which have undergone a major rearrangement of the ring system) give small peaks in the m/z 217 mass fragmentogram so these are usually detected using m/z 259 mass fragmentograms. In a few of the samples (especially B5, B6 and B8), this procedure was unsatisfactory due to major interferences with other compounds. This usually is not a problem with crude oils and must reflect the fact that these environmental samples contain large amounts of biogenic hydrocarbons and diagenetic compounds typical of recent sediments.

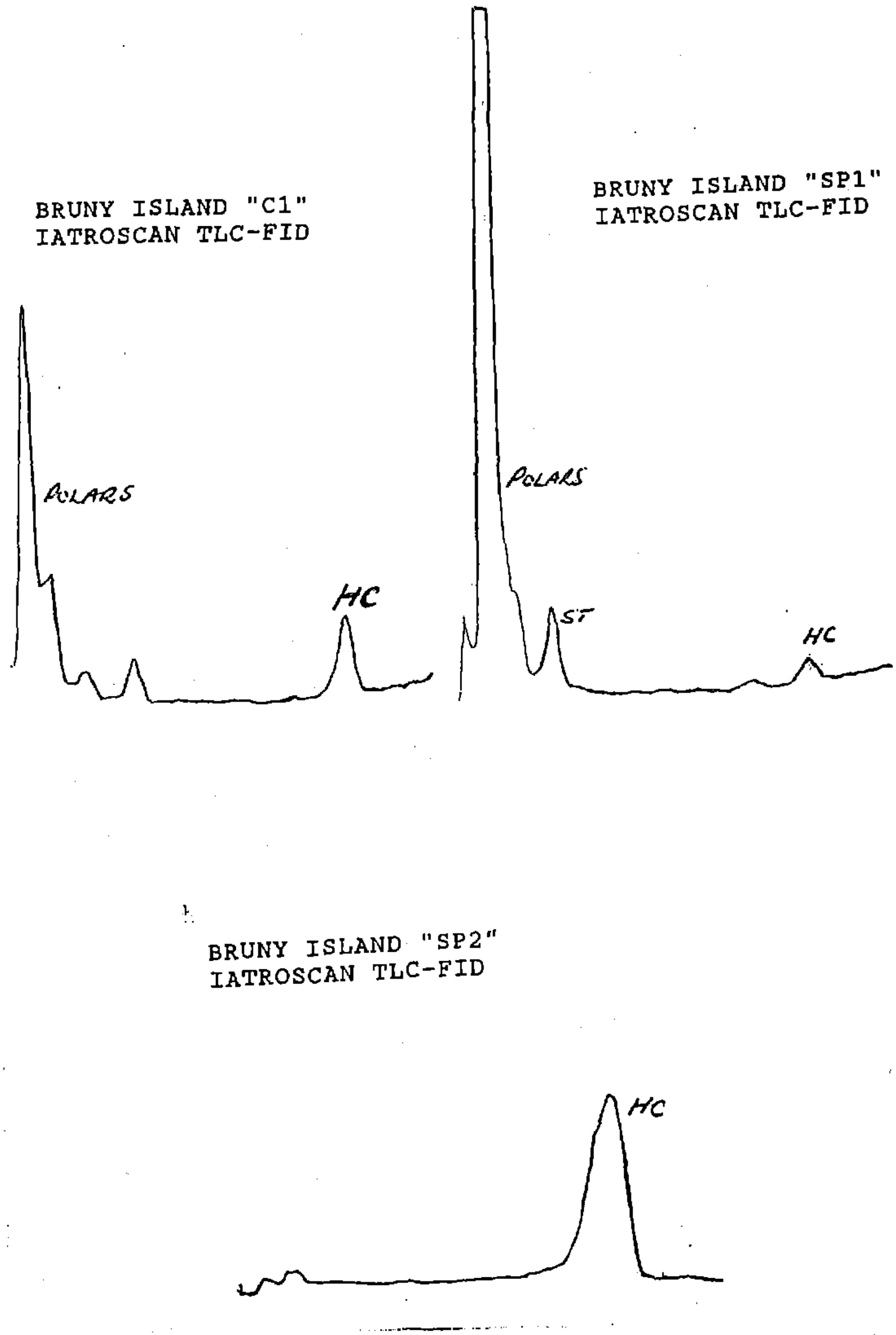


FIGURE 1. IATROSCAN TLC-FID CHROMATOGRAMS OF TOTAL EXTRACTABLE LIPIDS IN SAMPLES (a) BRUNY ISLAND "C1", (b) BRUNY ISLAND "SP1", (c) BRUNY ISLAND "SP2".

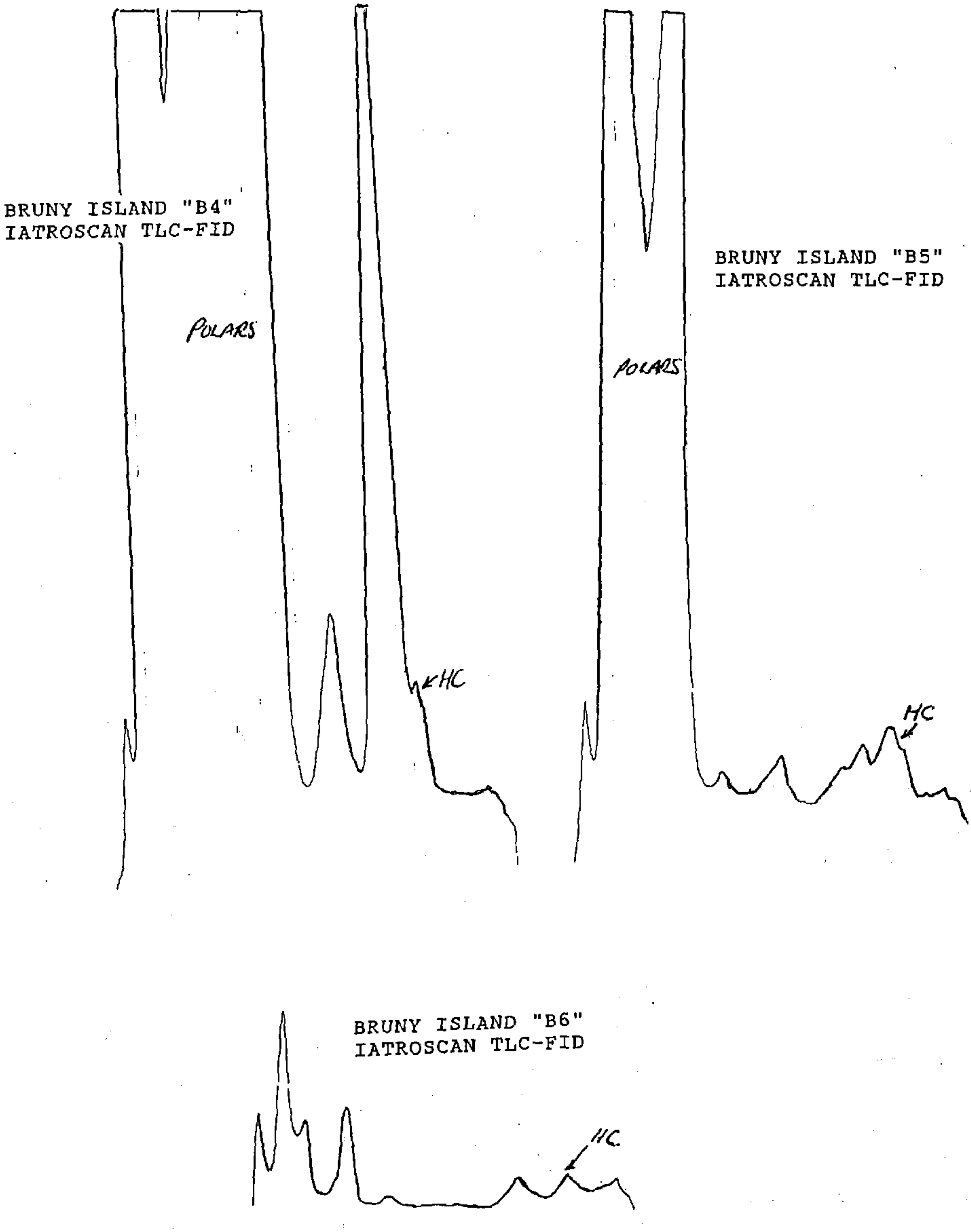


FIGURE 2. IATROSCAN TLC-FID CHROMATOGRAMS OF TOTAL EXTRACTABLE LIPIDS IN SAMPLES (a) BRUNY ISLAND "B4", (b) BRUNY ISLAND "B5", (c) BRUNY ISLAND "B6".

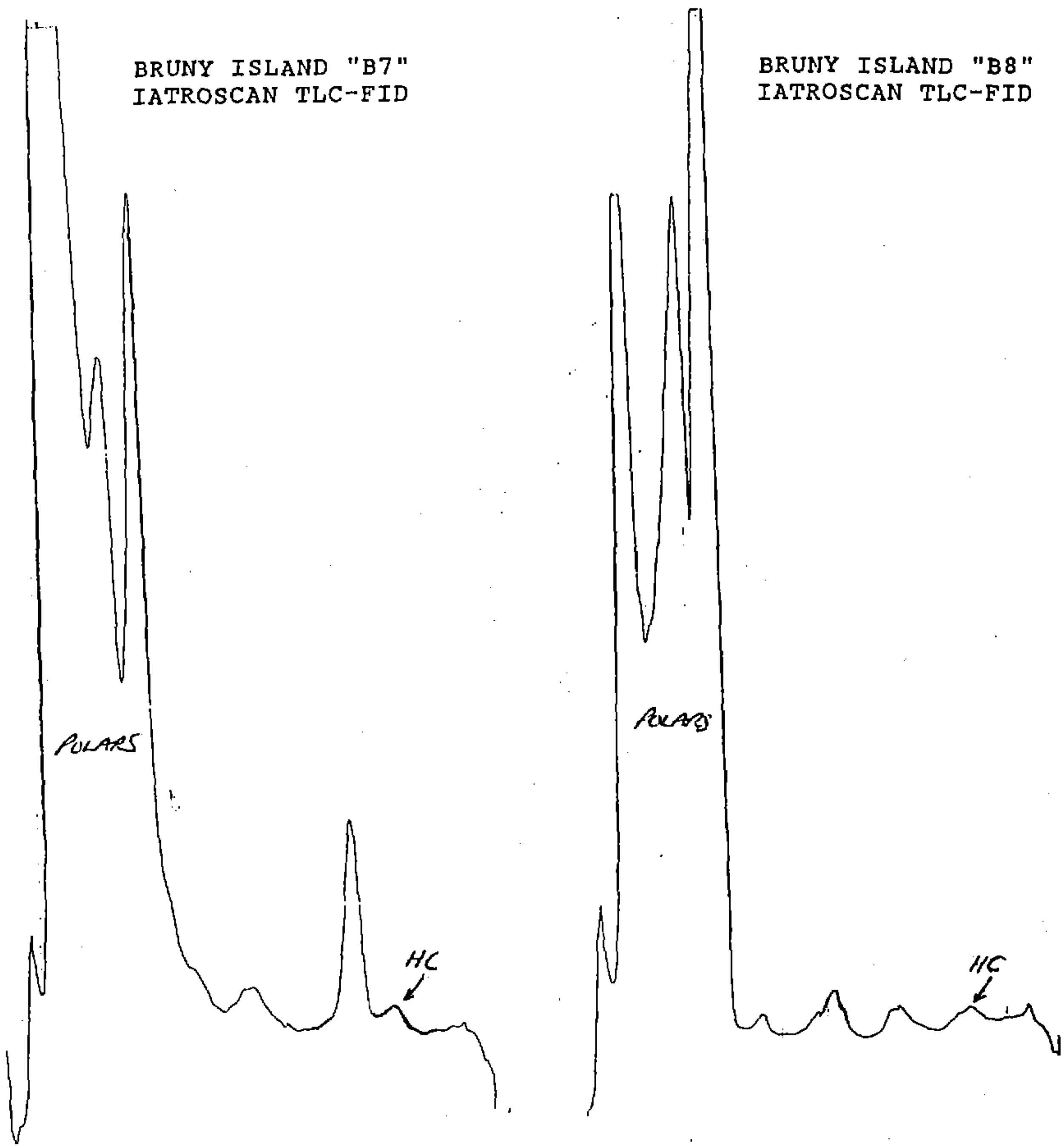


FIGURE 3. IATROSCAN TLC-FID CHROMATOGRAMS OF TOTAL EXTRACTABLE LIPIDS IN SAMPLES (a) BRUNY ISLAND "B7", (b) BRUNY ISLAND "B8".

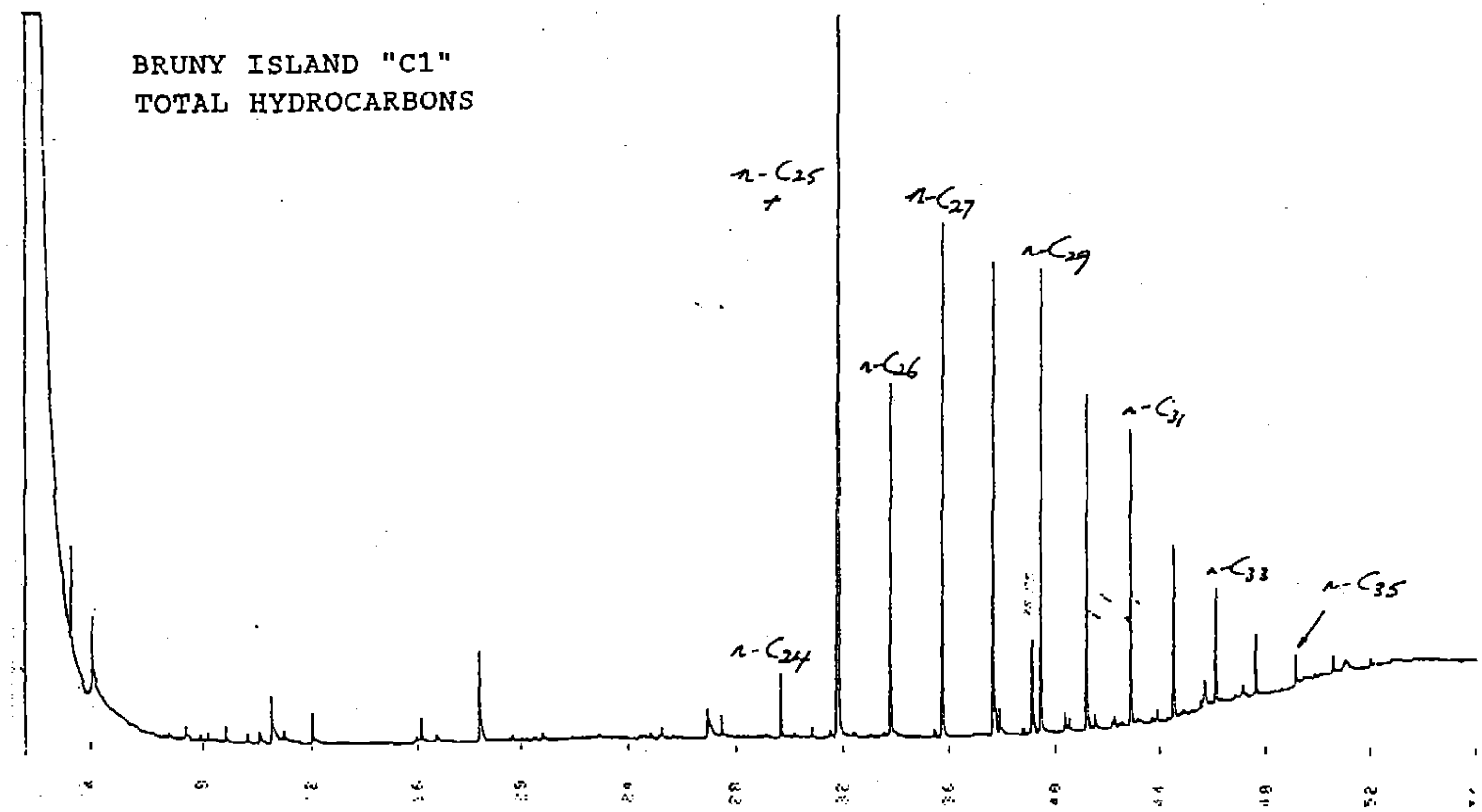


FIGURE 4. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "C1".

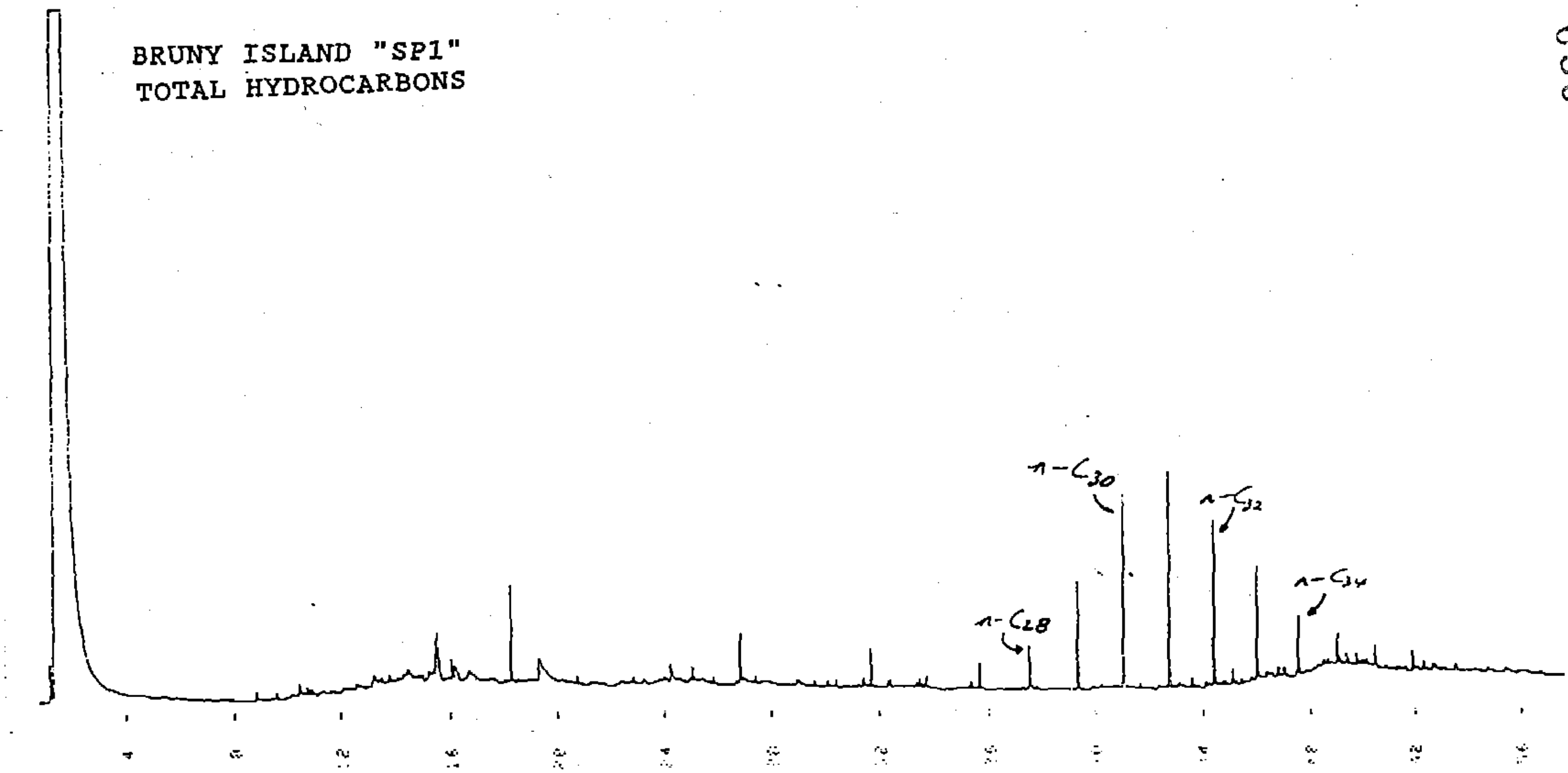


FIGURE 5. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "SP1".

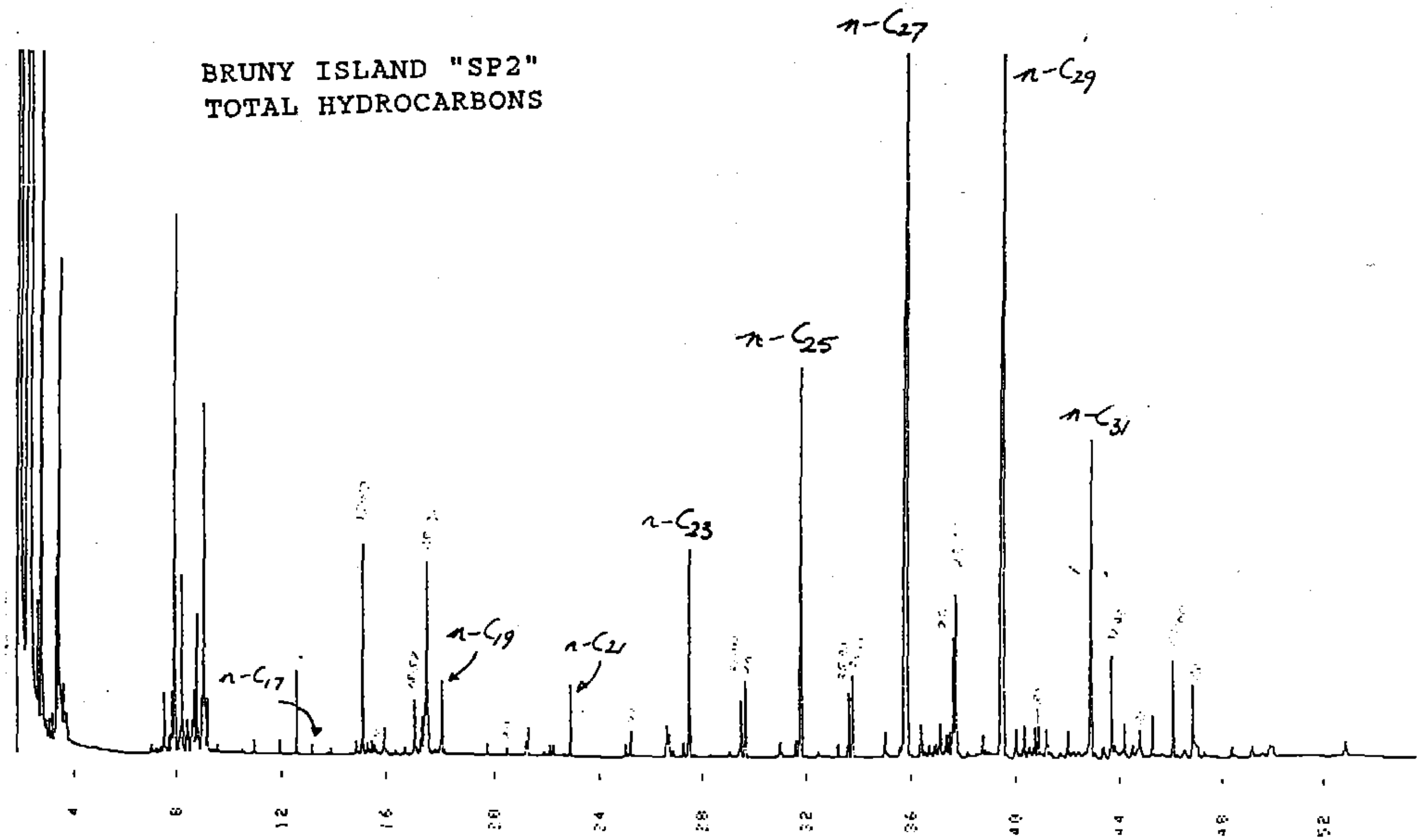


FIGURE 6. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "SP2".

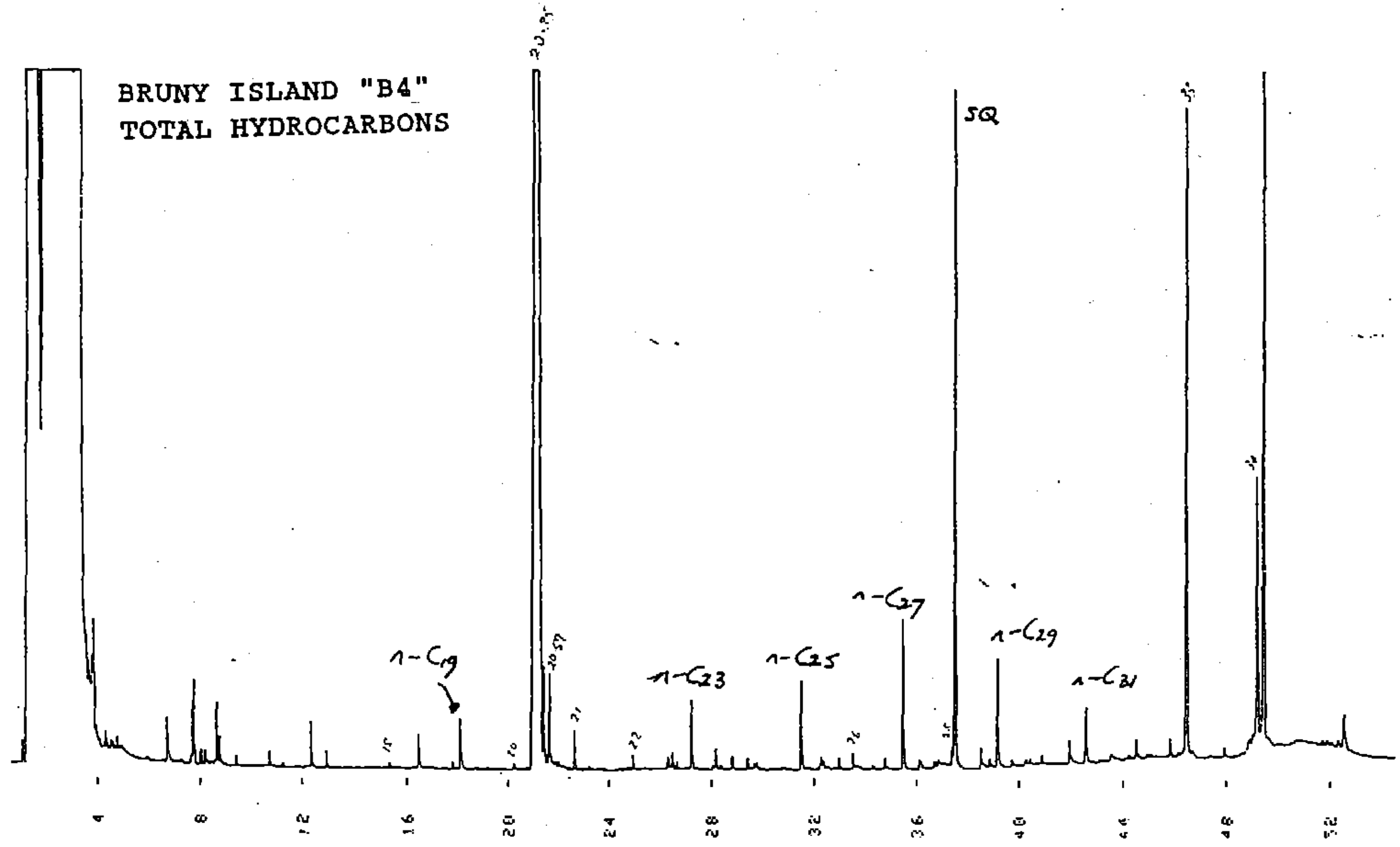


FIGURE 7. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "B4".

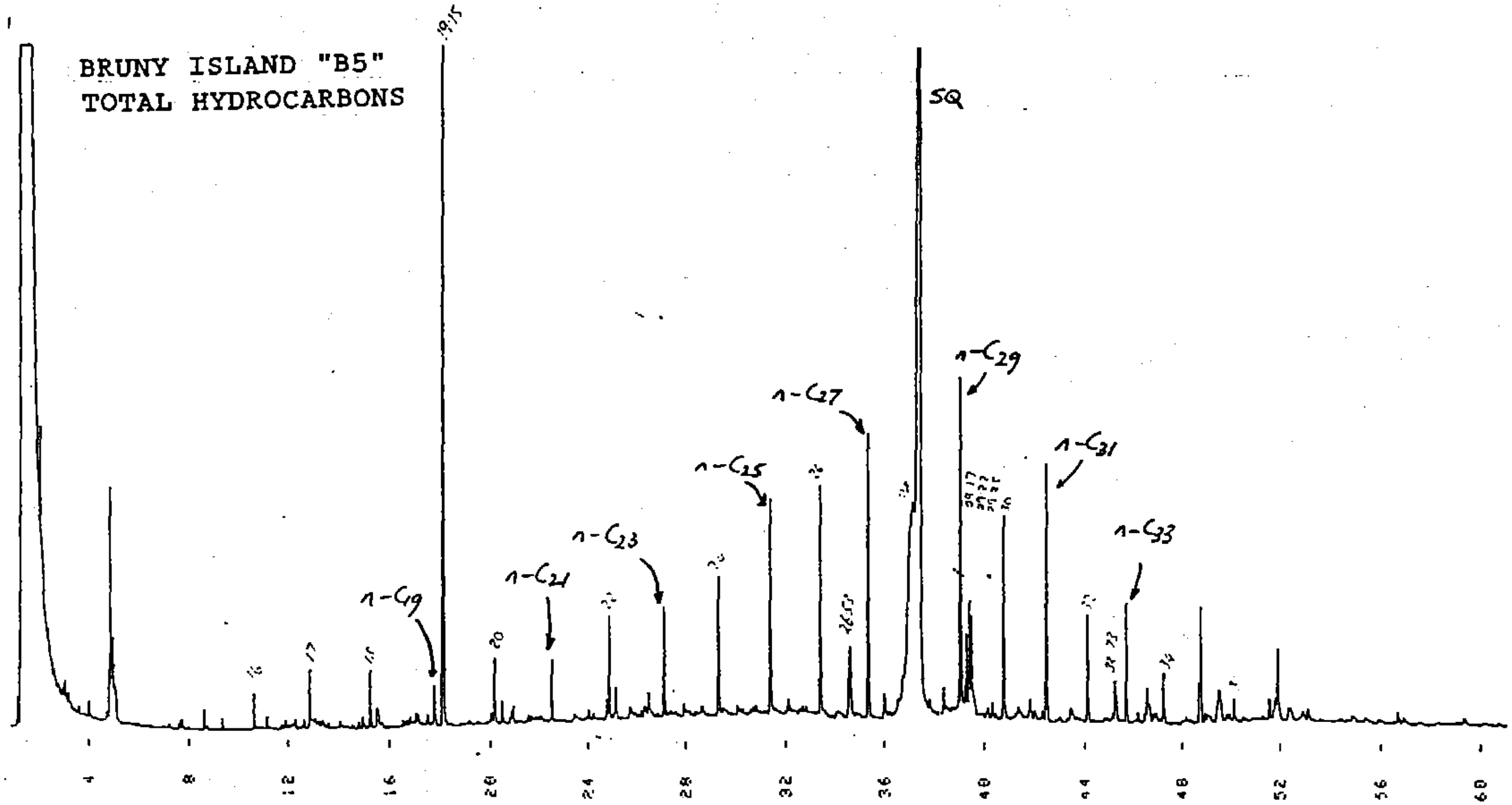


FIGURE 8. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "B5".

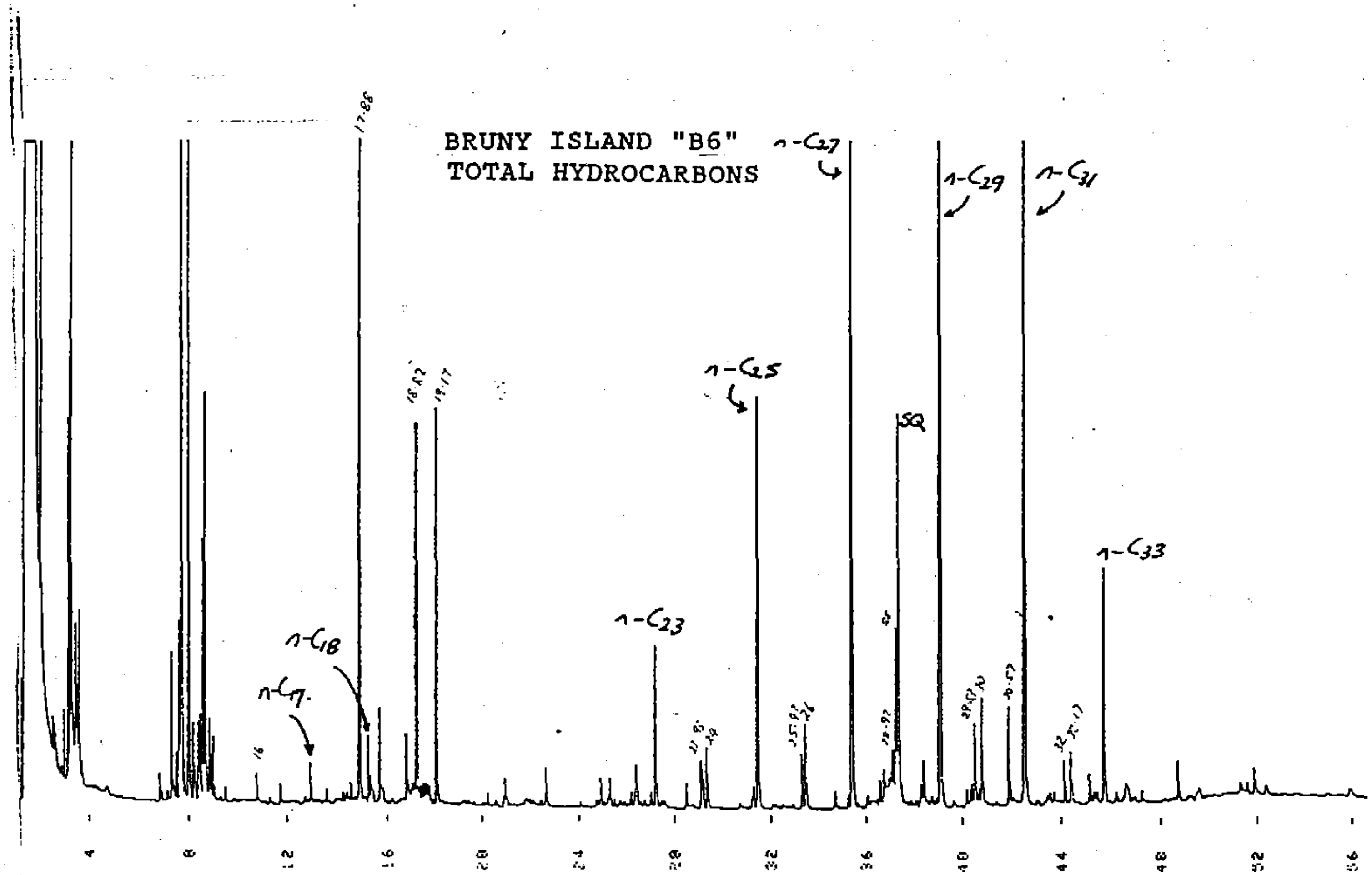


FIGURE 9. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "B6".

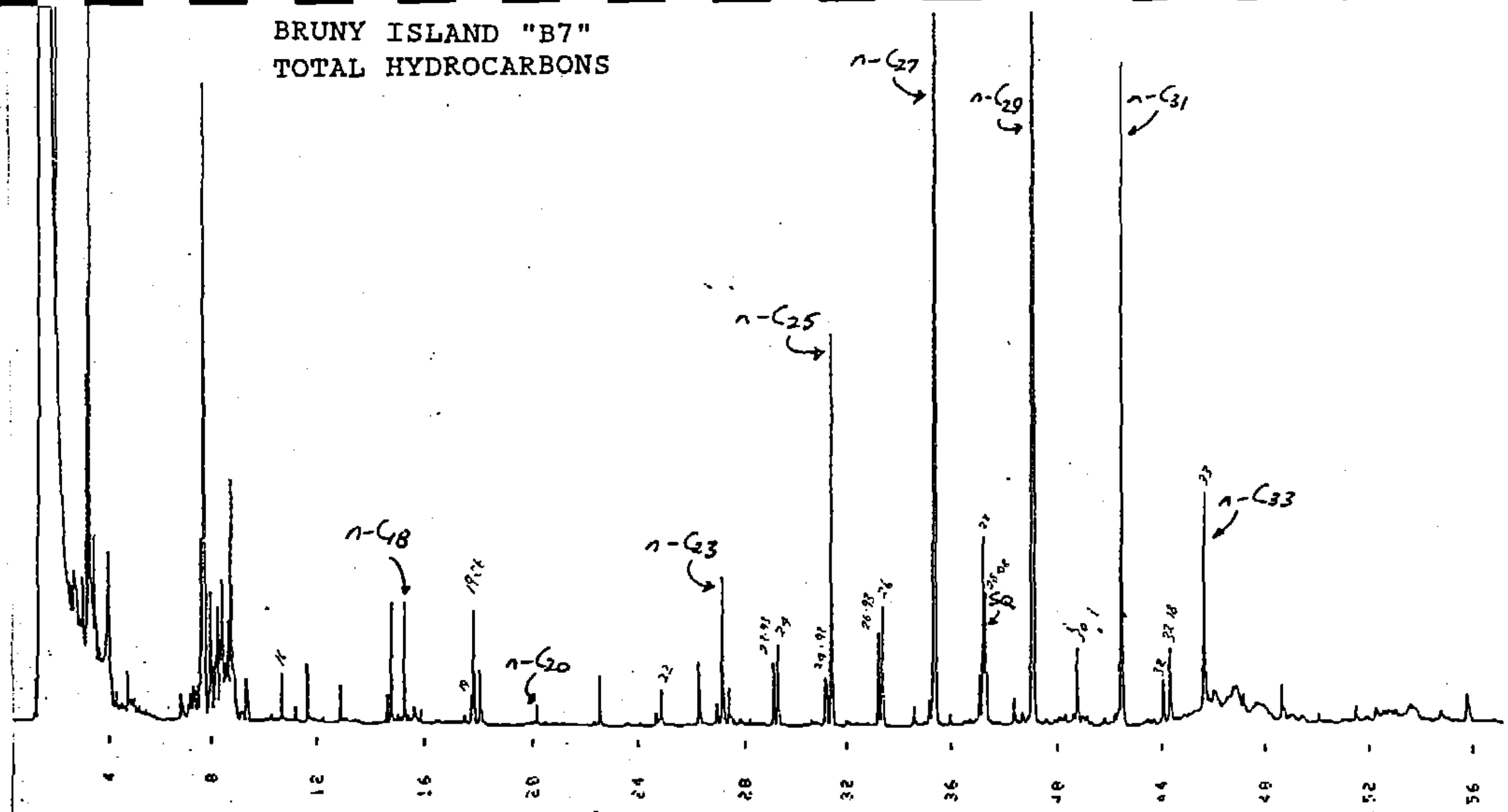


FIGURE 10. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "B7".

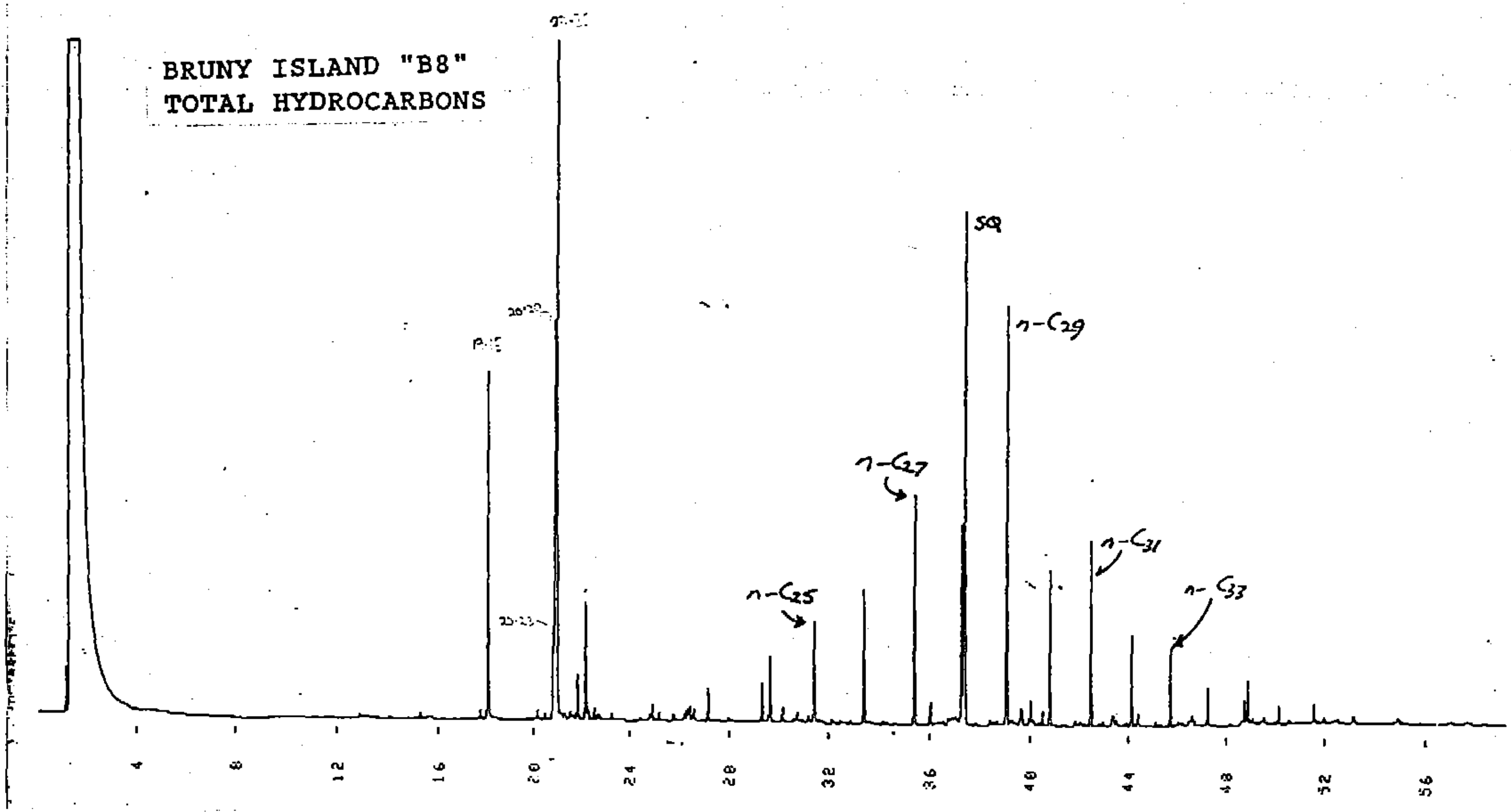


FIGURE 11. CAPILLARY GAS CHROMATOGRAM OF TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "B8".

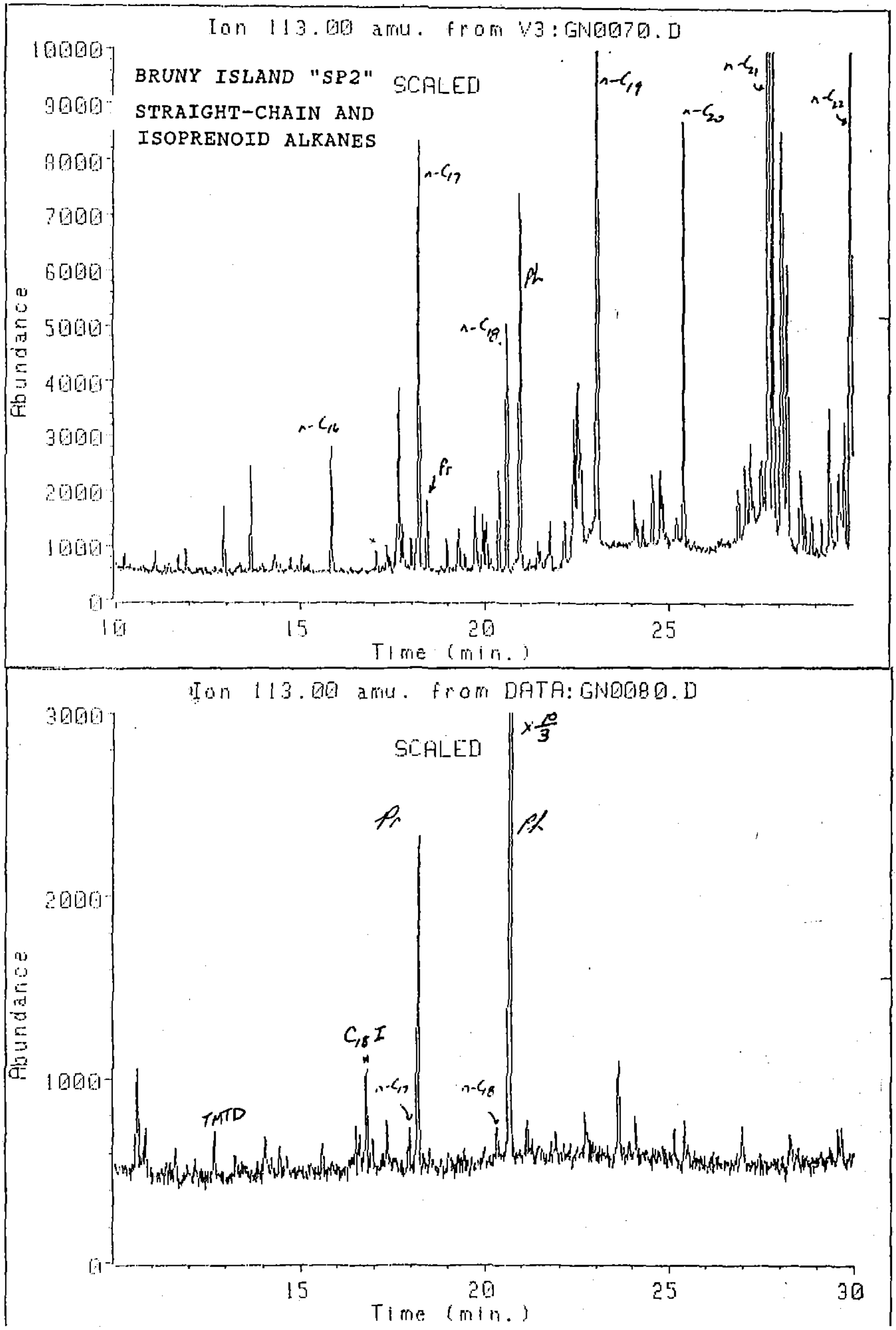


FIGURE 12A. STRAIGHT-CHAIN AND ISOPRENOID ALKANES IN TOTAL HYDROCARBONS FROM BRUNY ISLAND SAMPLE "SP2".
FIGURE 12B. ISOPRENOID ALKANES IN BRANCHED/CYC[illegible]

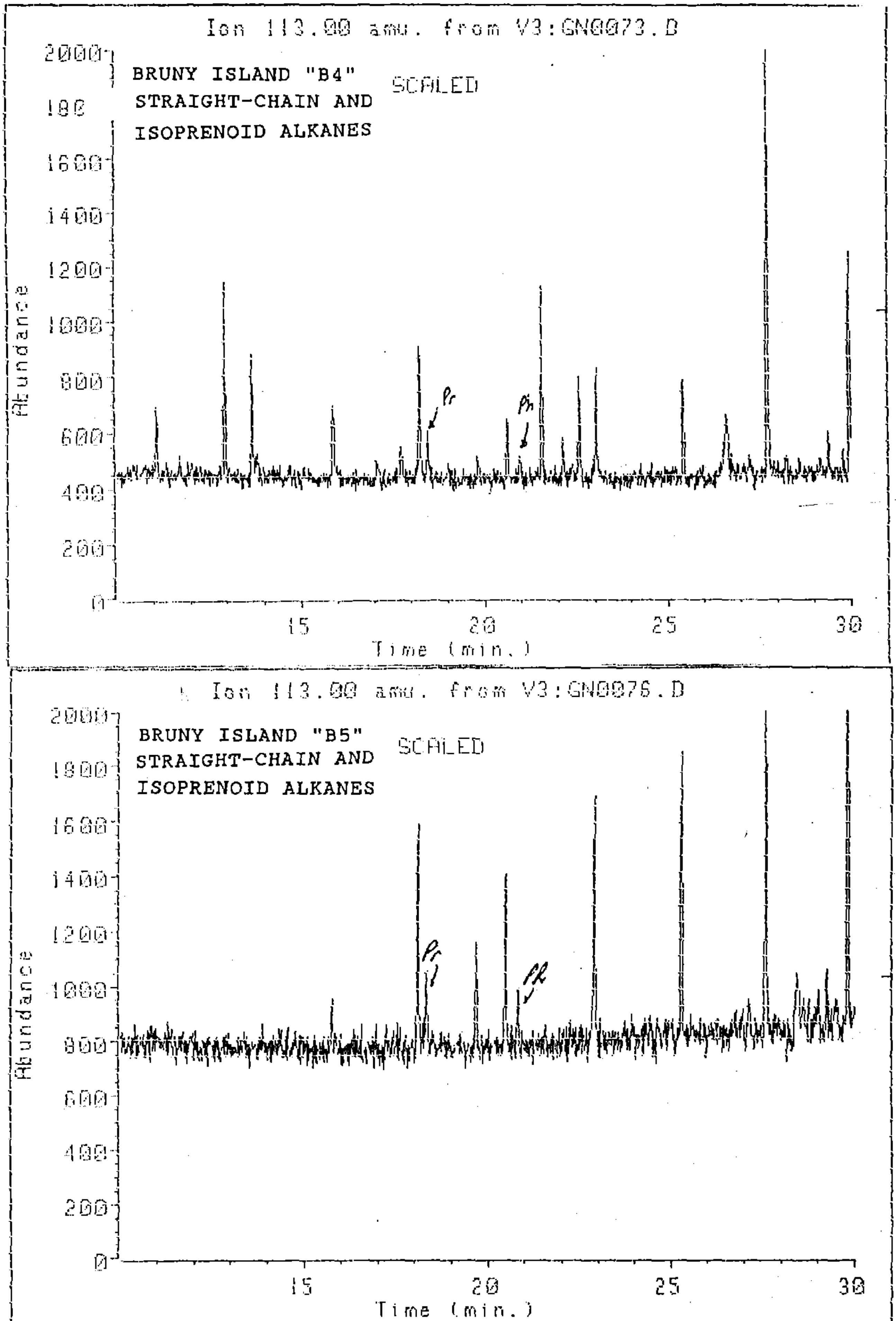


FIGURE 13. STRAIGHT-CHAIN AND ISOPRENOID ALKANES FROM TOTAL HYDROCARBONS IN (a) BRUNY ISLAND SAMPLE "B4", (b) BRUNY ISLAND SAMPLE "B5"

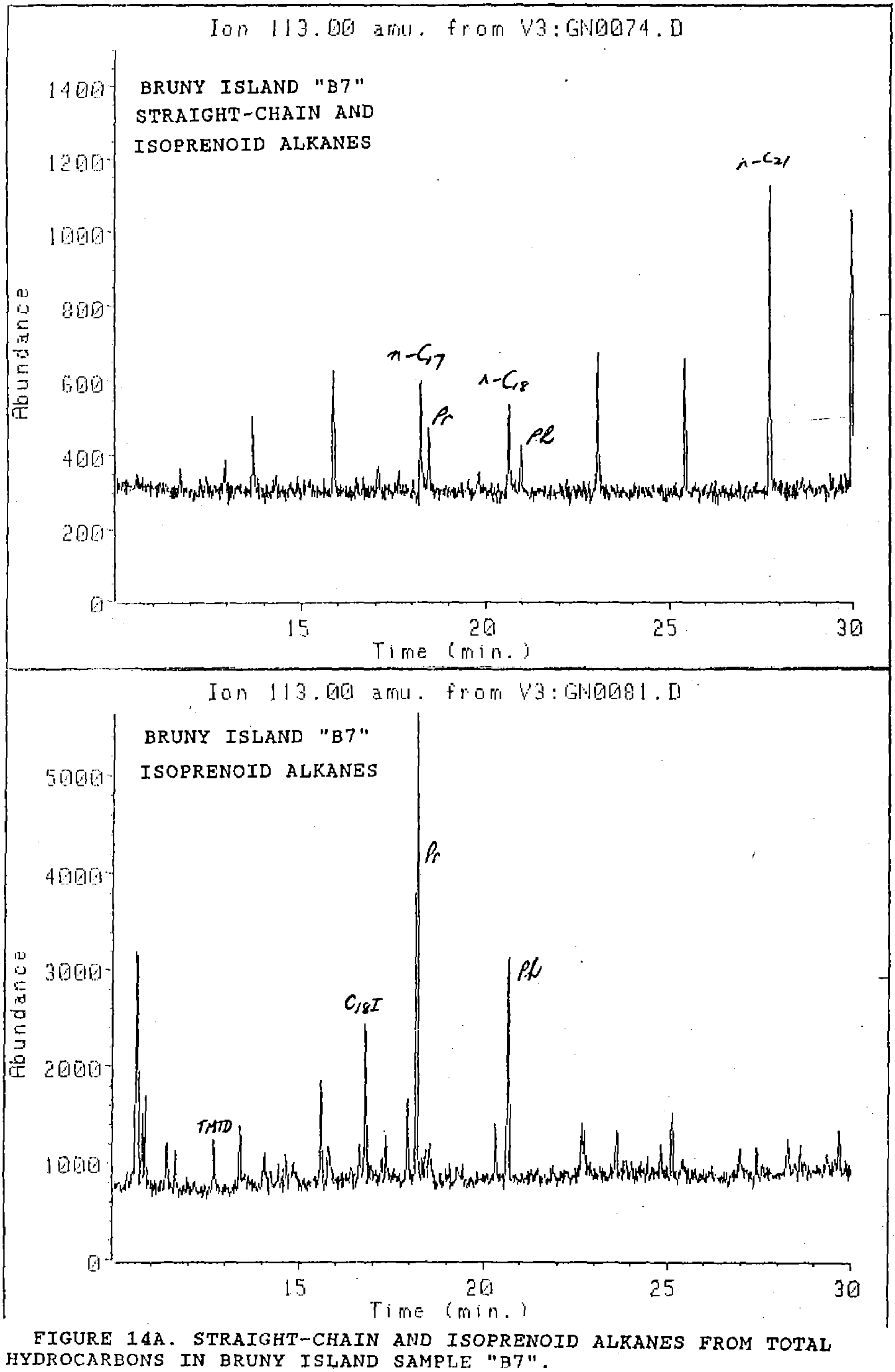
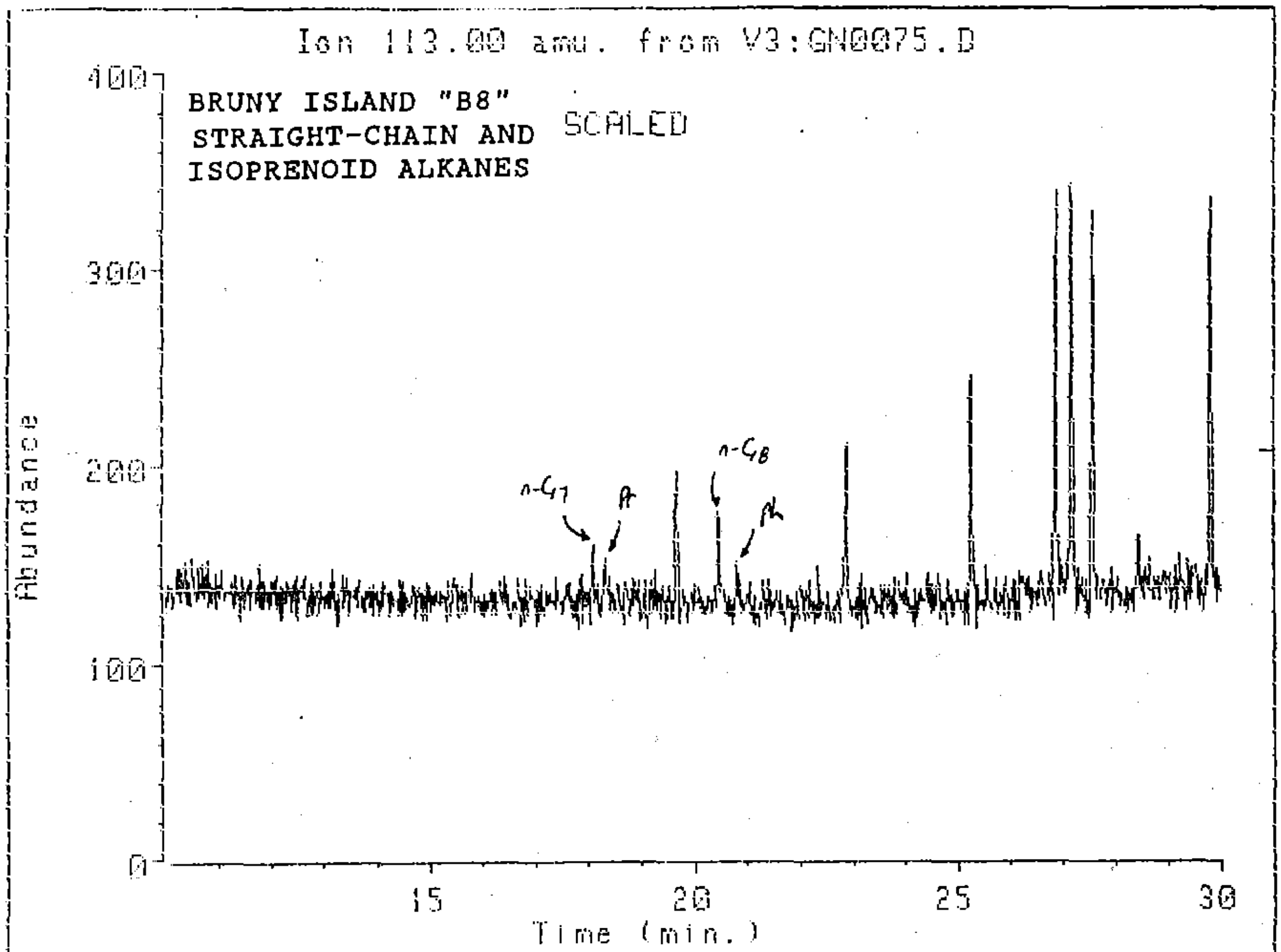


FIGURE 14A. STRAIGHT-CHAIN AND ISOPRENOID ALKANES FROM TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "B7".
FIGURE 14B. ISOPRENOID ALKANES FROM BRANCHED/CYCLIC ALKANE



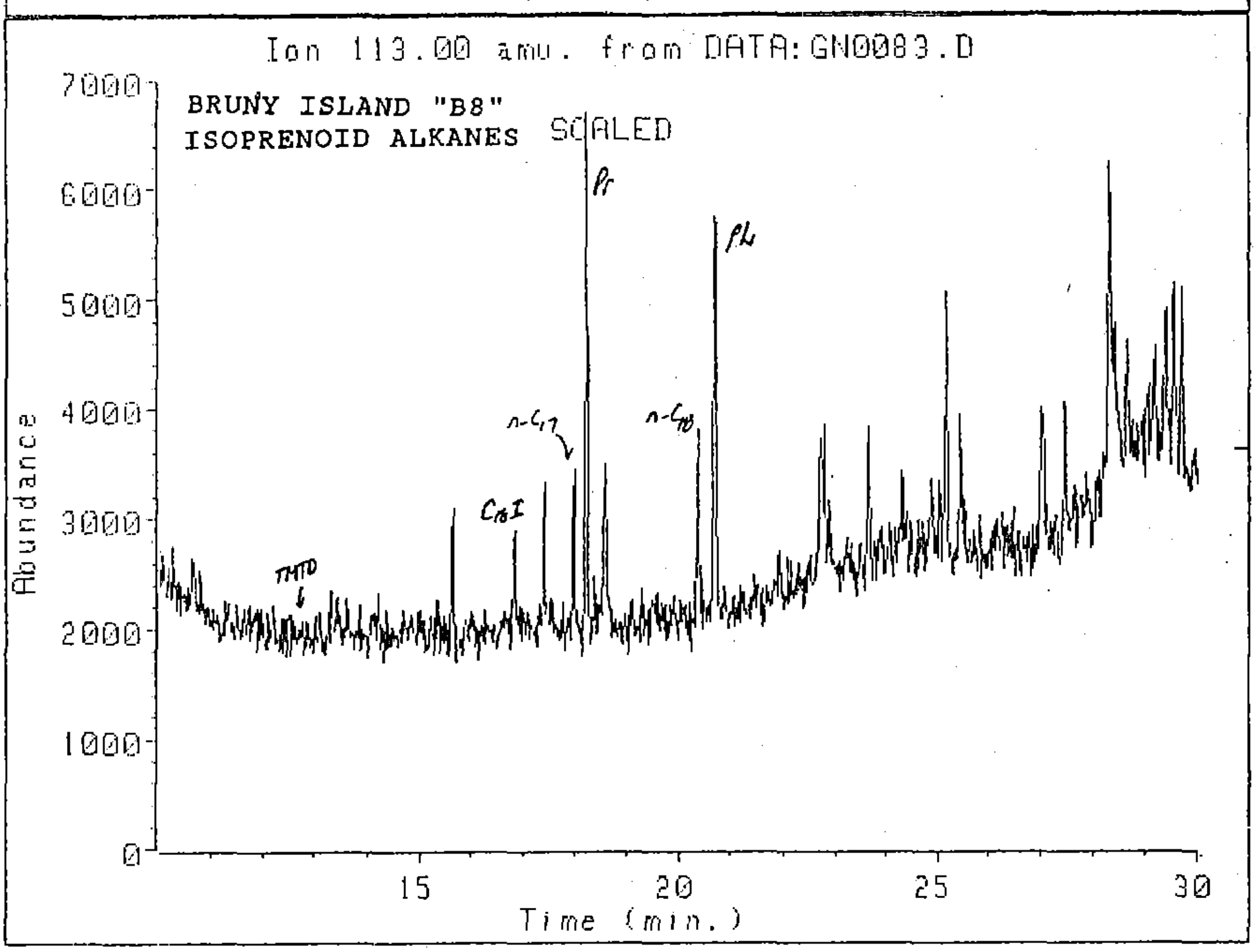


FIGURE 15A. STRAIGHT-CHAIN AND ISOPRENOID ALKANES FROM TOTAL HYDROCARBONS IN BRUNY ISLAND SAMPLE "B8".

FIGURE 15B. ISOPRENOID ALKANES FROM BRANCHED/CYCLIC ALKANE FRACTION FROM BRUNY ISLAND SAMPLE "B8".

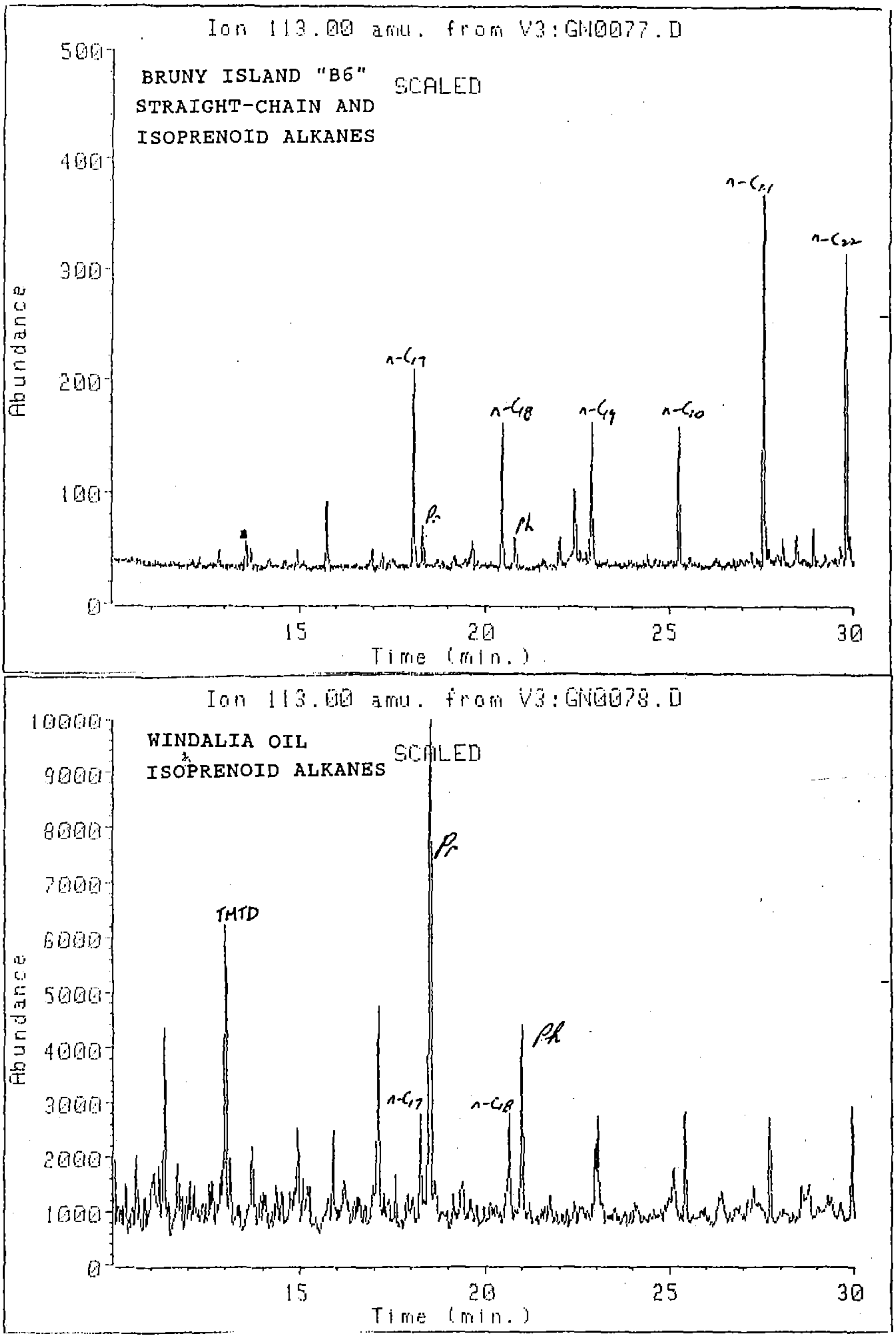


FIGURE 16A. STRAIGHT-CHAIN AND ISOPRENOID ALKANES FROM TOTAL HYDROCARBONS FROM BRUNY ISLAND SAMPLE "B6"

FIGURE 16B. ISOPRENOID ALKANES FROM REFERENCE OIL SAMPLE WINDALIA OIL.

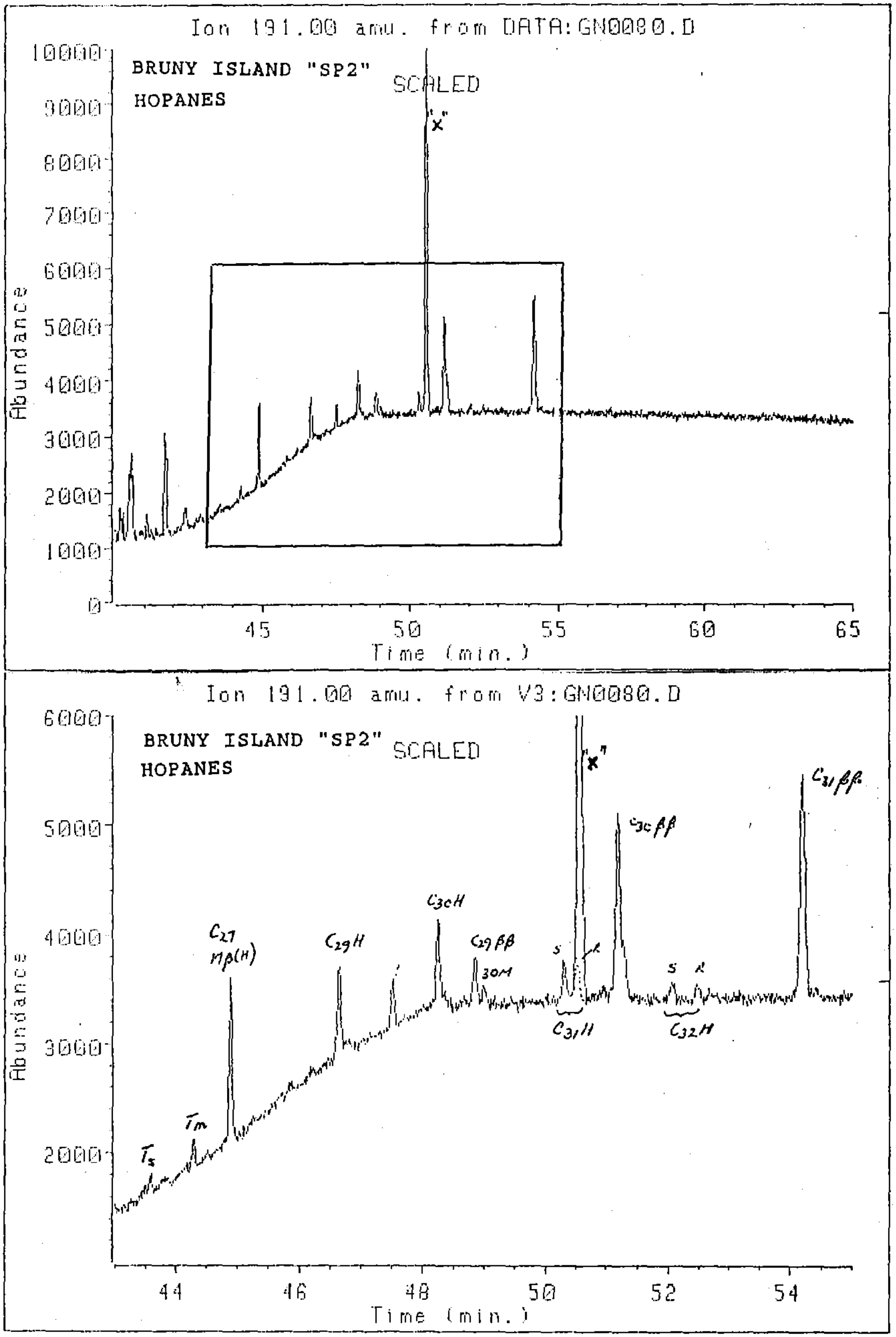


FIGURE 17. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES AND OTHER TERPANES) IN BRUNY ISLAND SAMPLE "SP2".

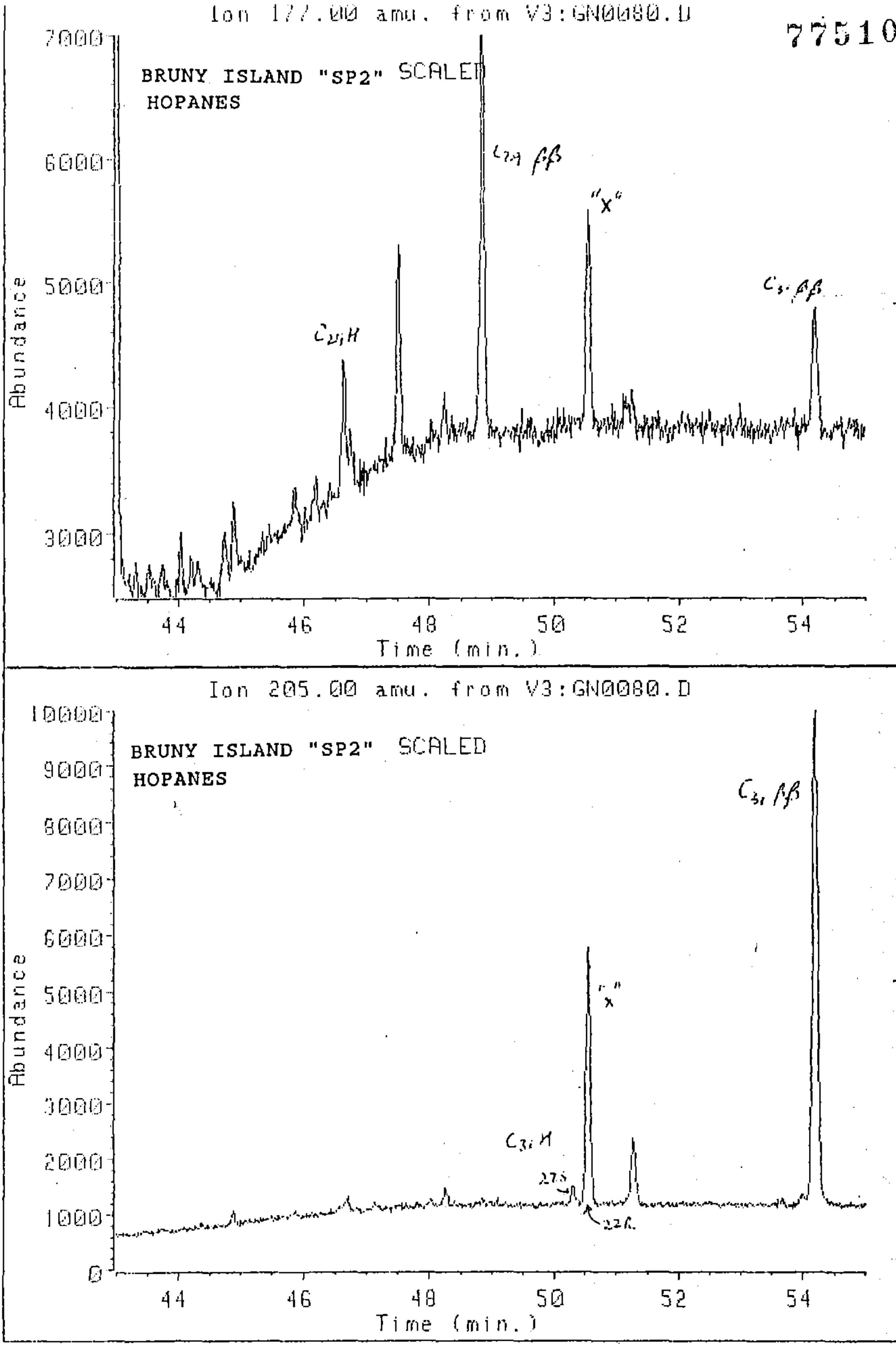


FIGURE 18A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES AND ALSO DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "SP2".

FIGURE 18B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "SP2".

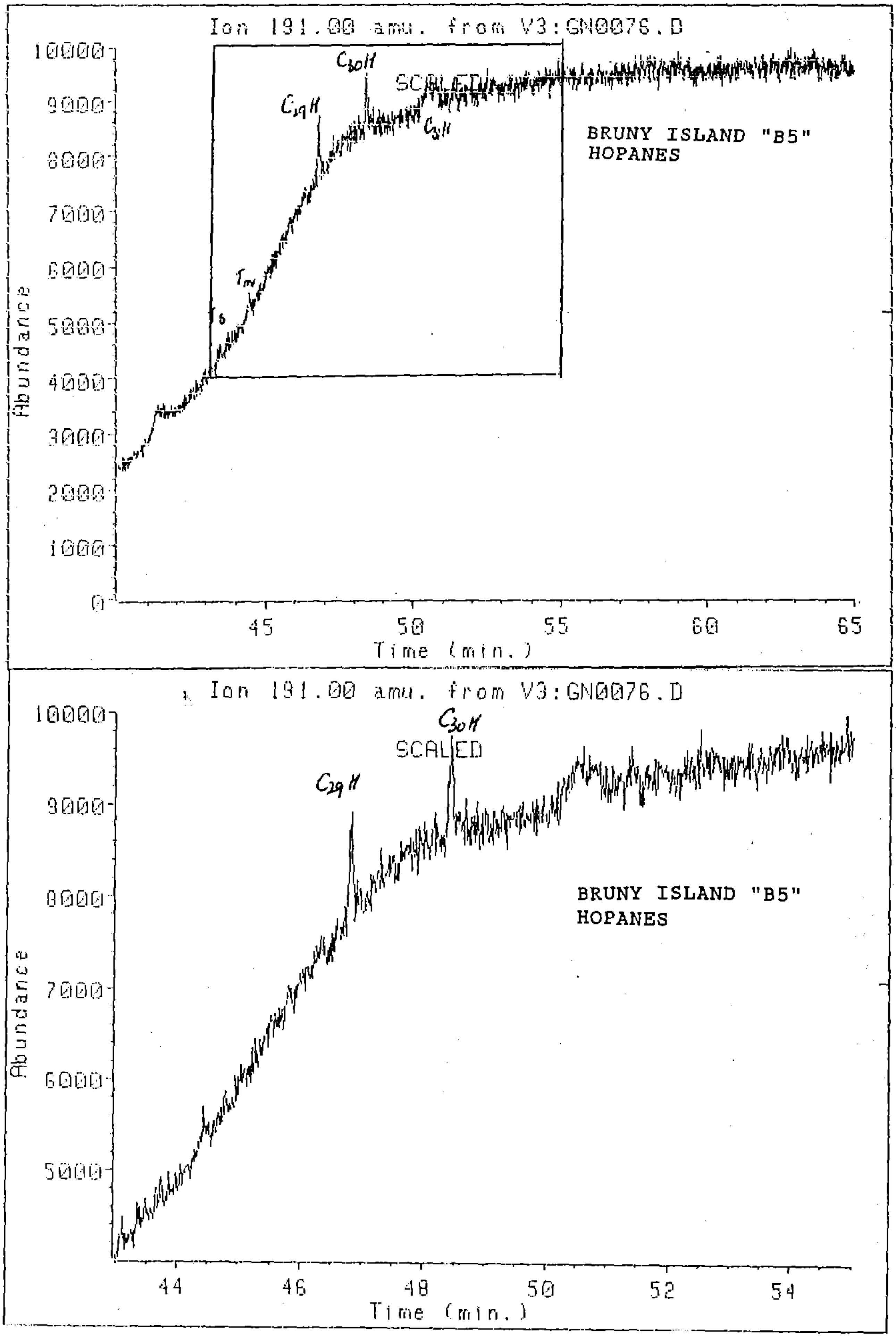


FIGURE 19. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES AND OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B5".

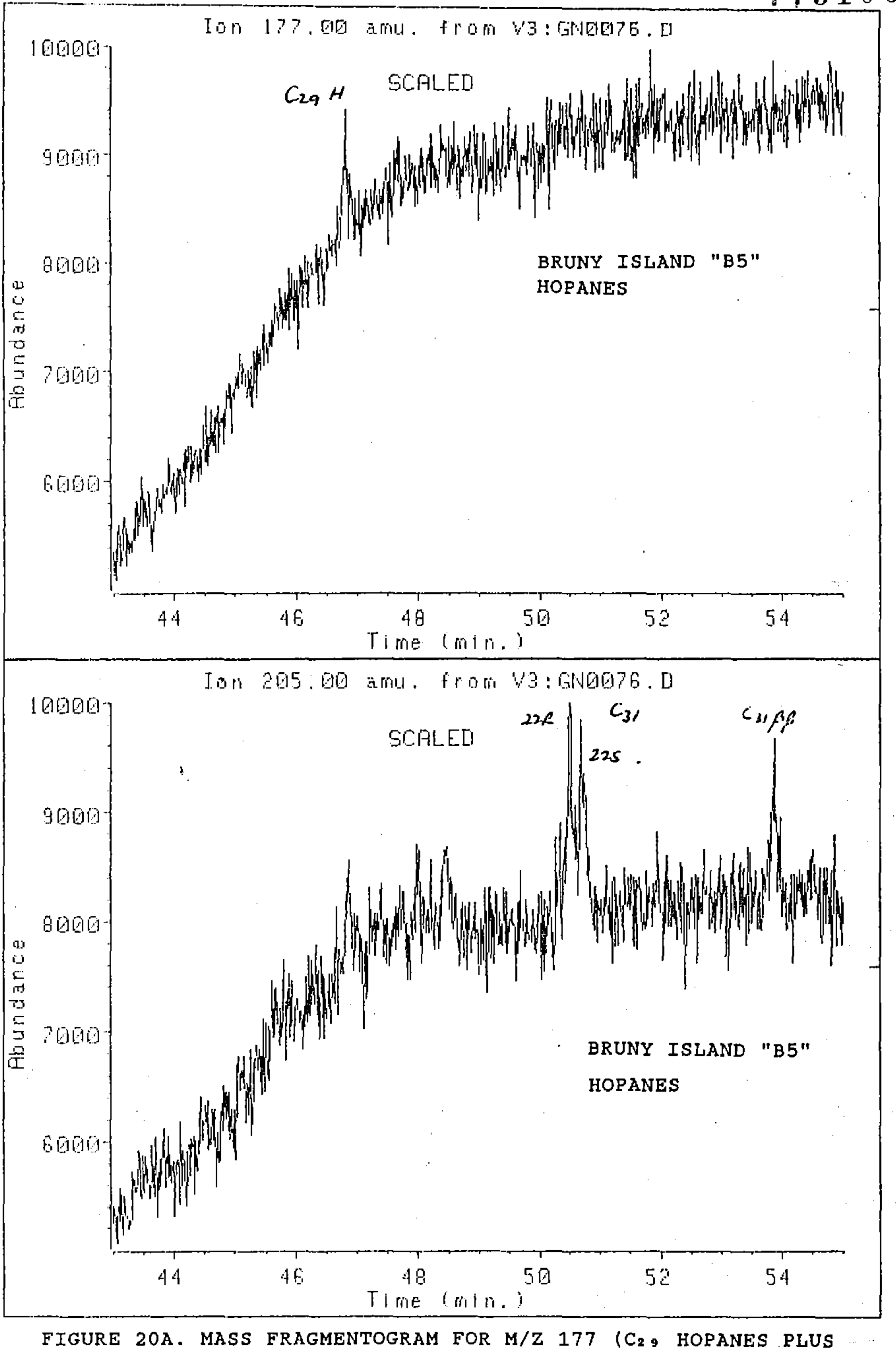


FIGURE 20A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B5".

FIGURE 20B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "B5".

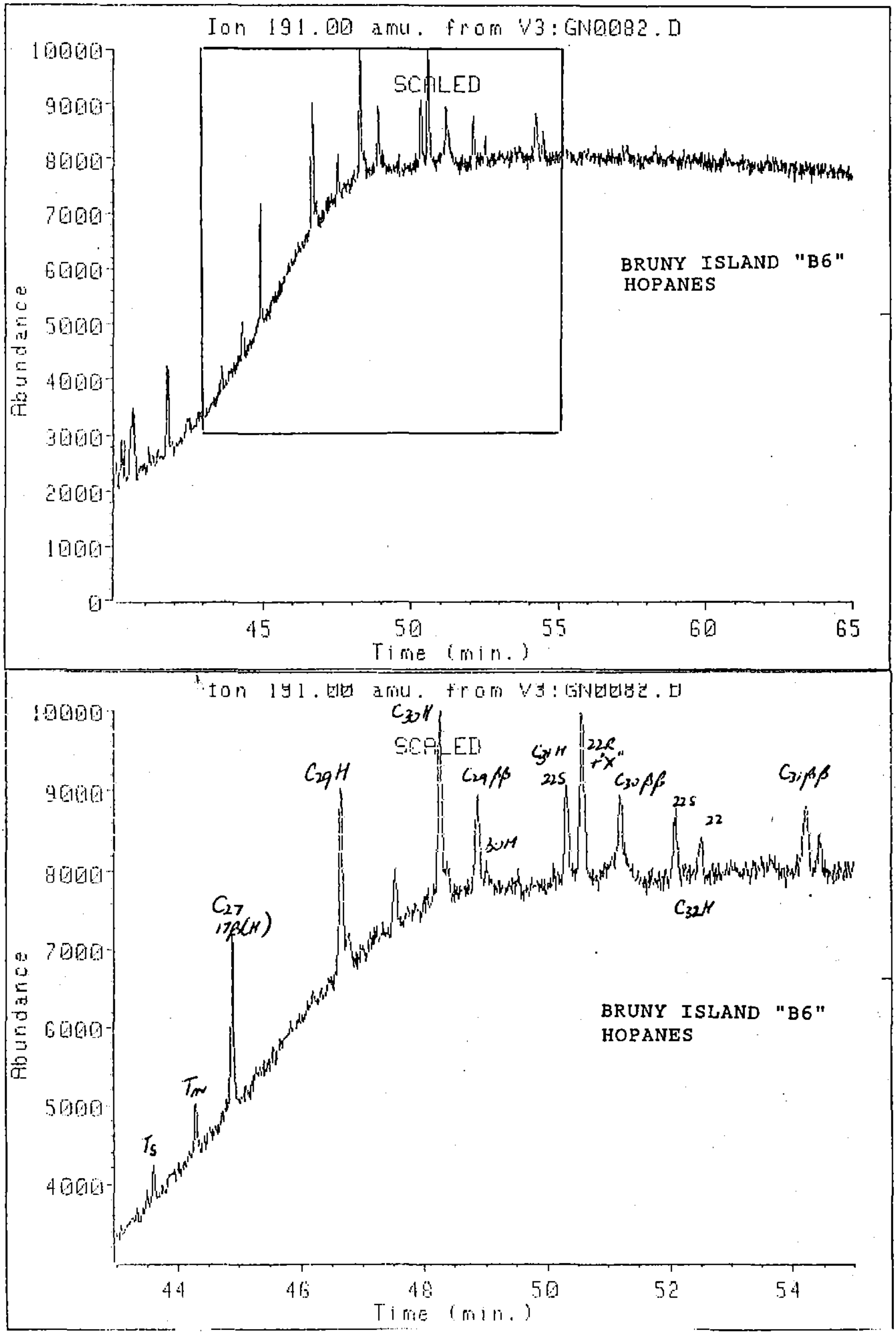


FIGURE 21. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES AND OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B6".

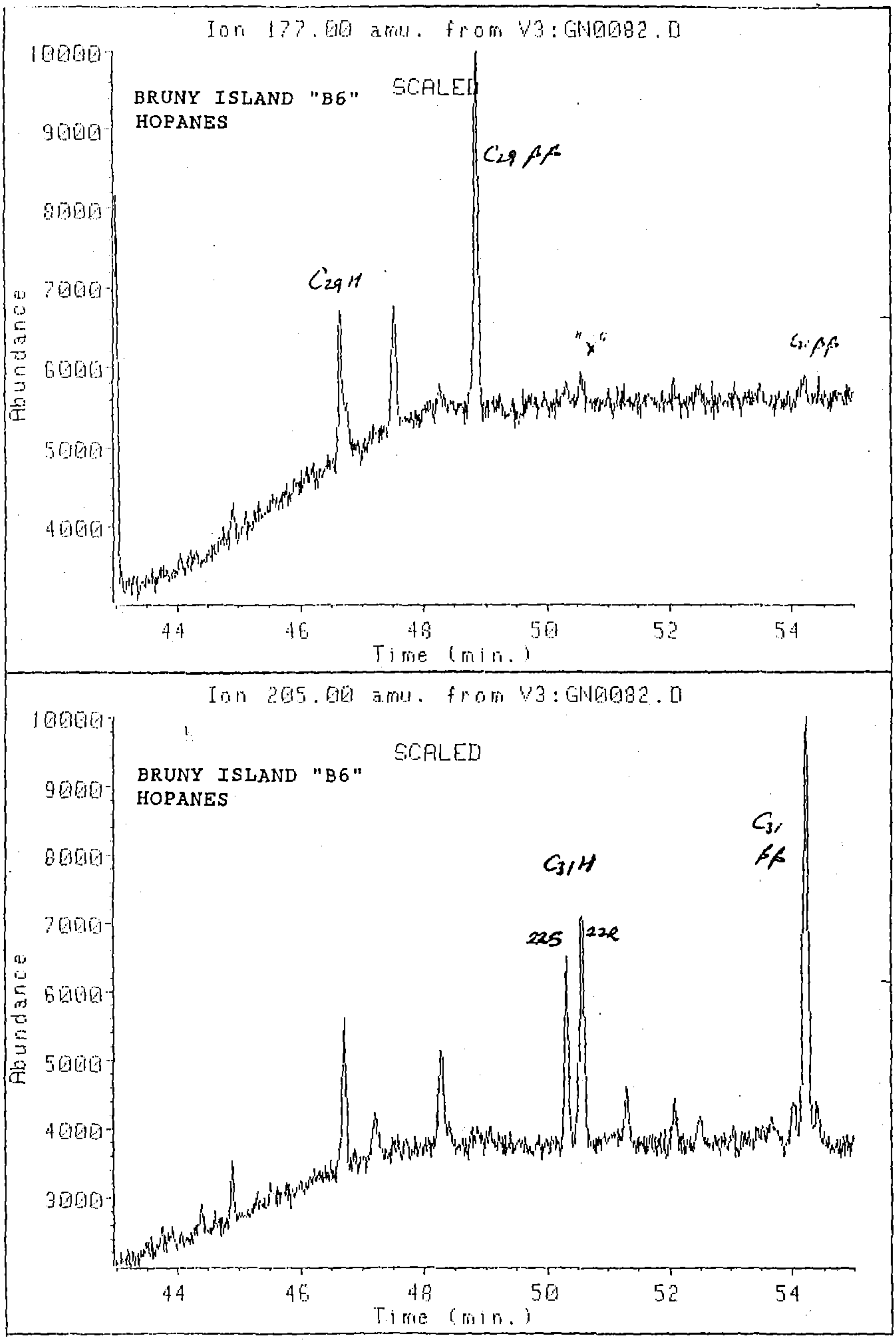


FIGURE 22A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B6".

FIGURE 22B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN ... SAMPLE "B6".

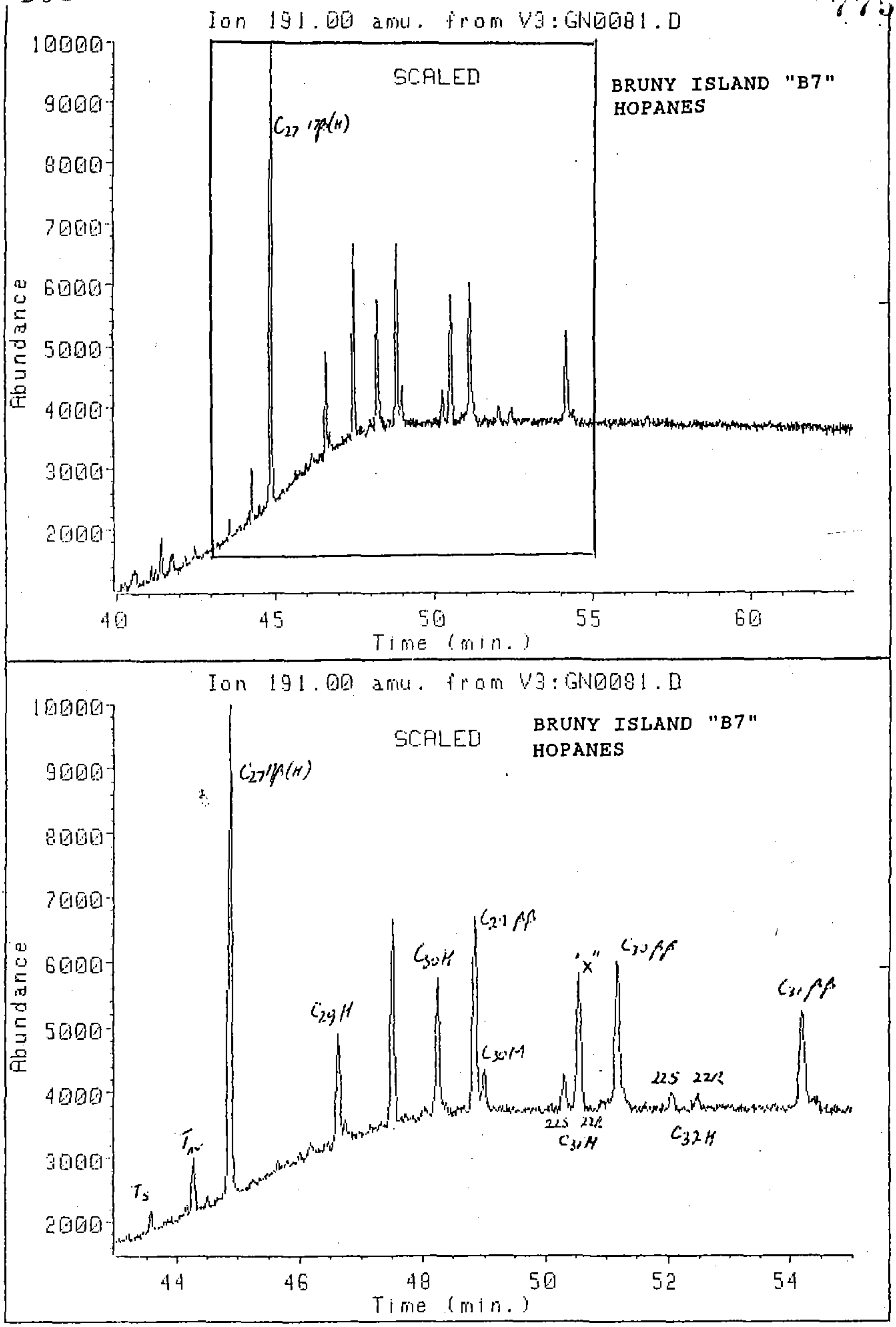
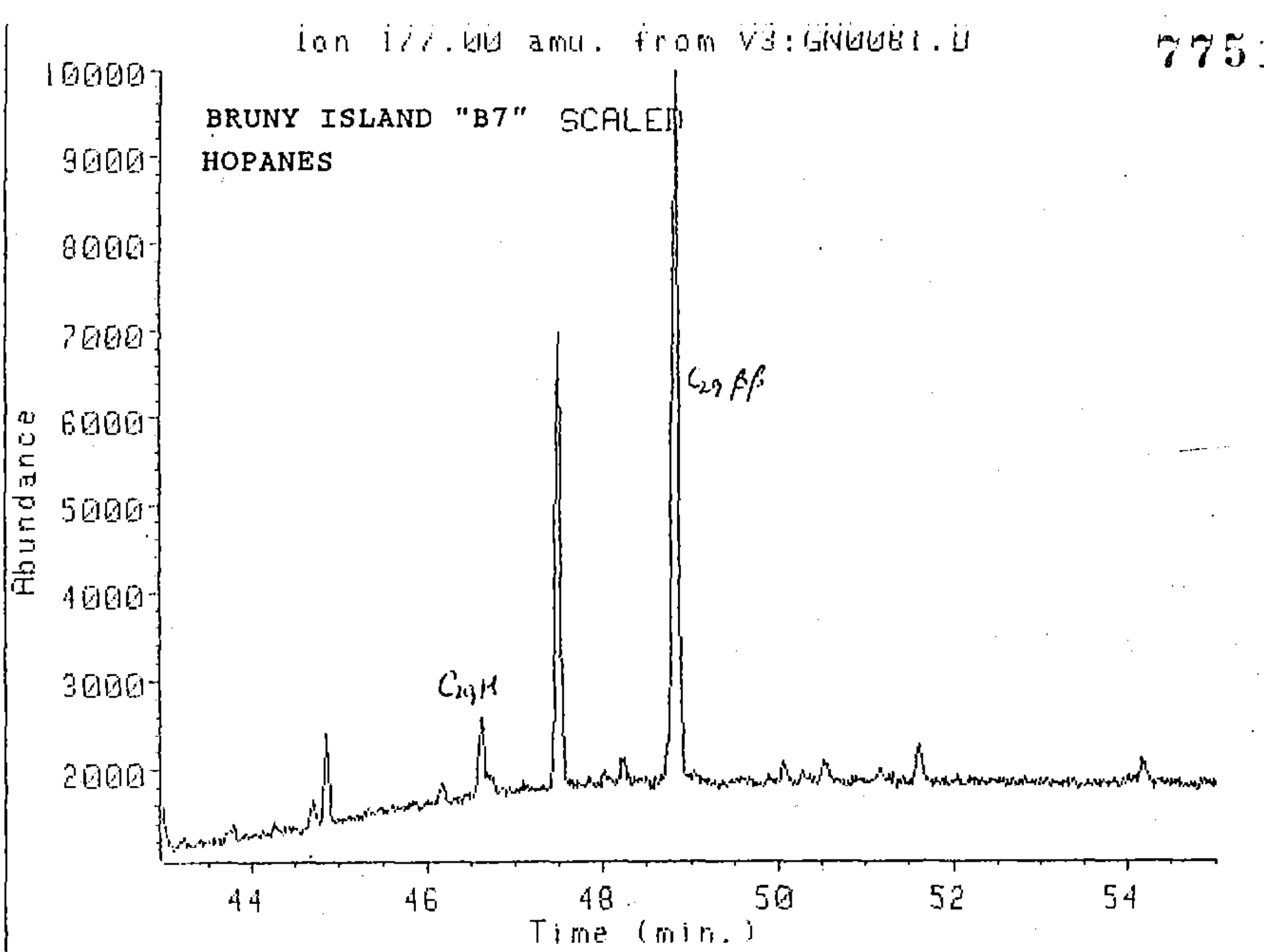


FIGURE 23. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES PLUS OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B7".



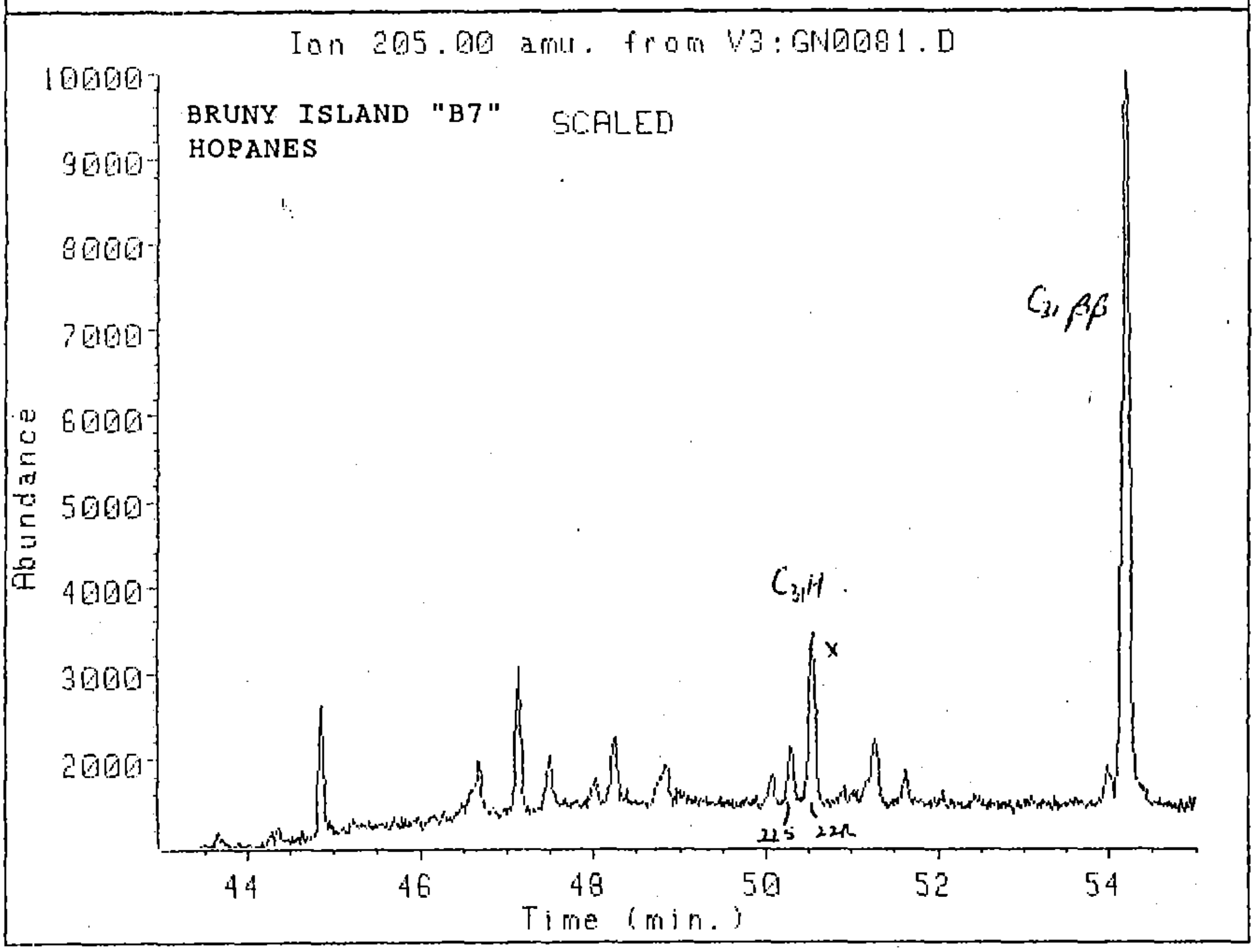


FIGURE 24A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B7".

FIGURE 24B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "B7".

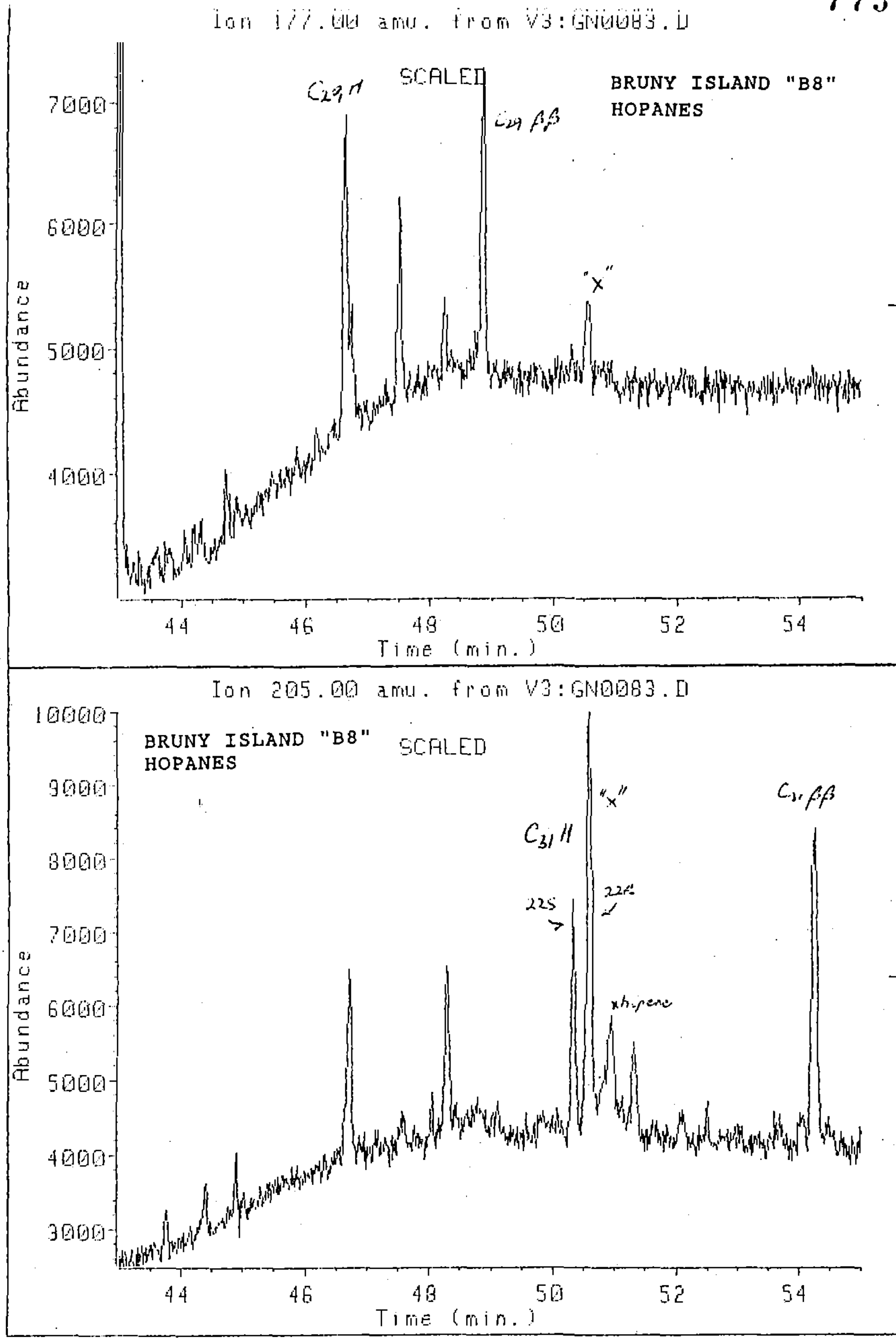
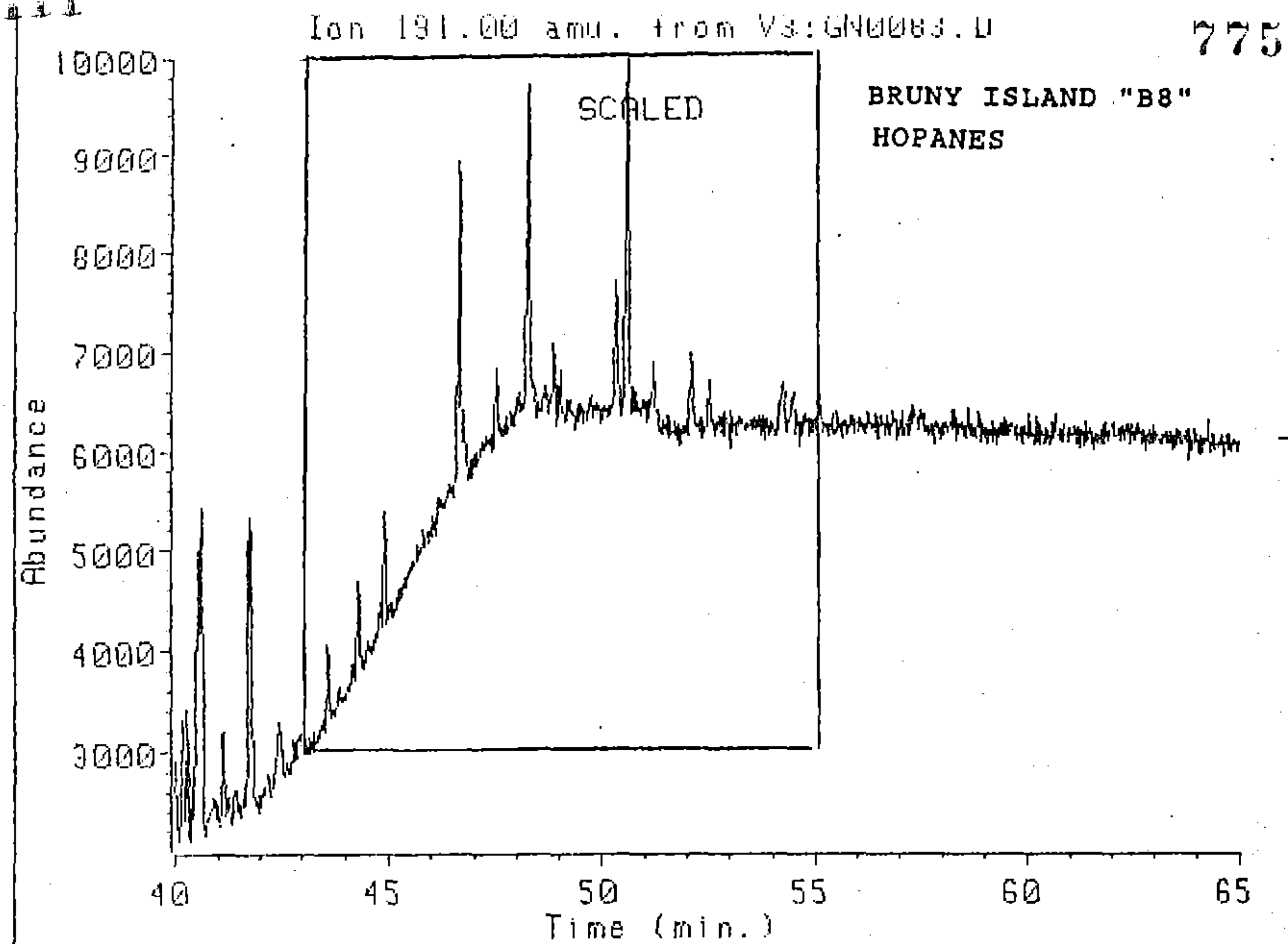


FIGURE 25. MASS FRAGMENTOGRAMS FOR M/Z 191 (HOPANES PLUS OTHER TRITERPANES) IN BRUNY ISLAND SAMPLE "B8".



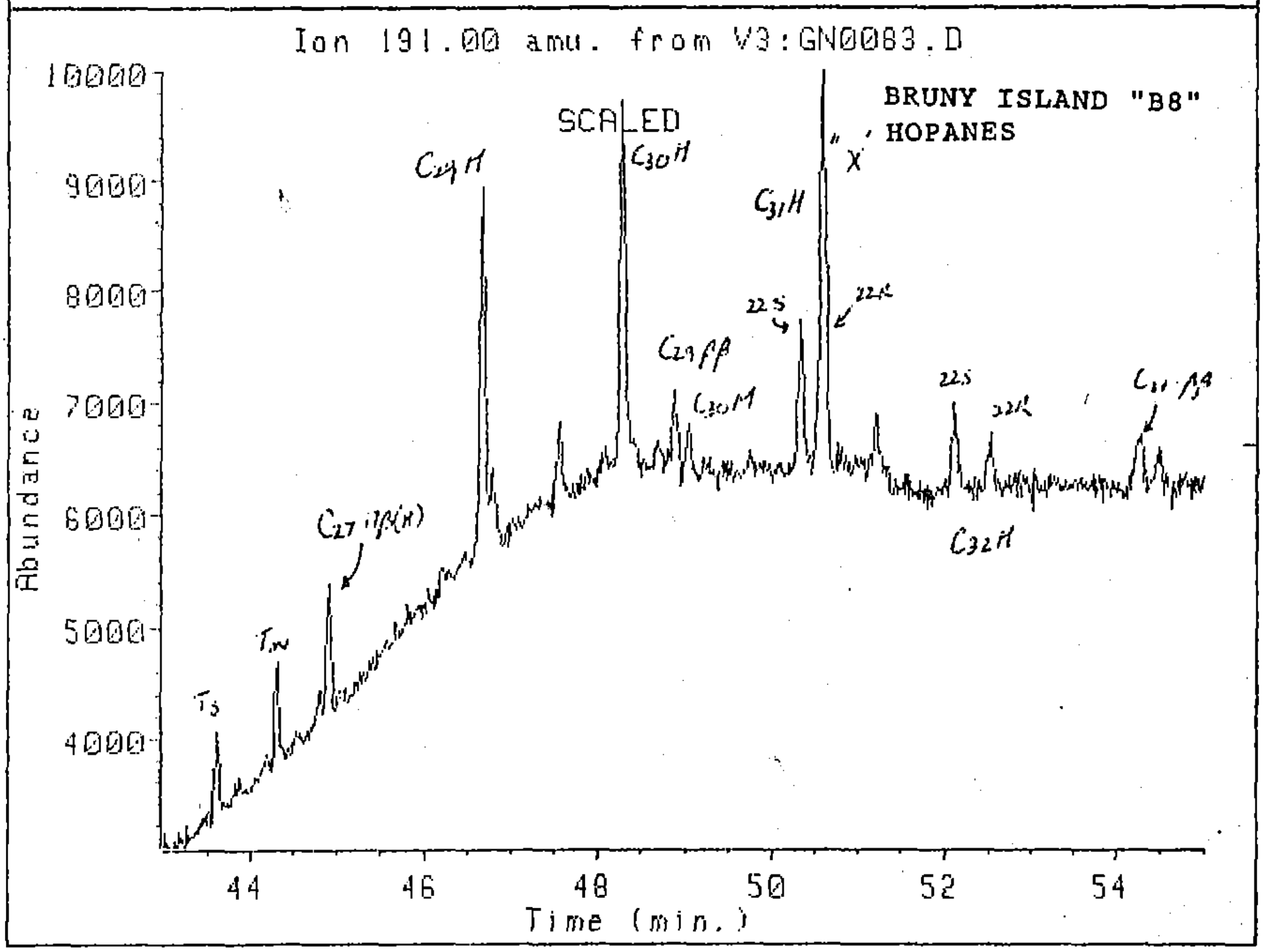


FIGURE 25A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN BRUNY ISLAND SAMPLE "B8".

FIGURE 25B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) IN BRUNY ISLAND SAMPLE "B8".

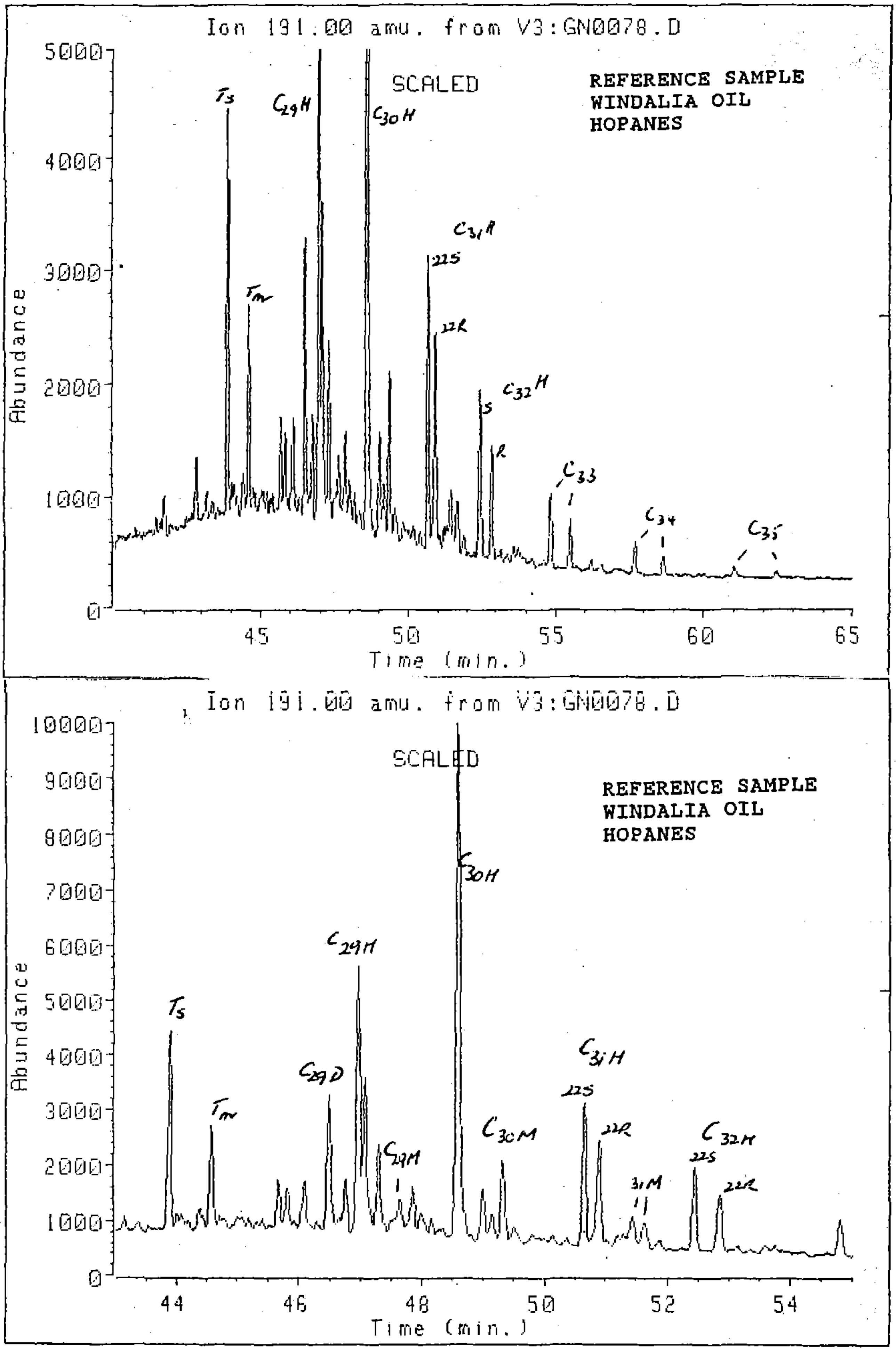


FIGURE 26. MASS FRAGMENTOGRAM FOR M/Z 191 (HOPANES PLUS OTHER TRITERPANES) IN REFERENCE SAMPLE WINDALIA OIL.

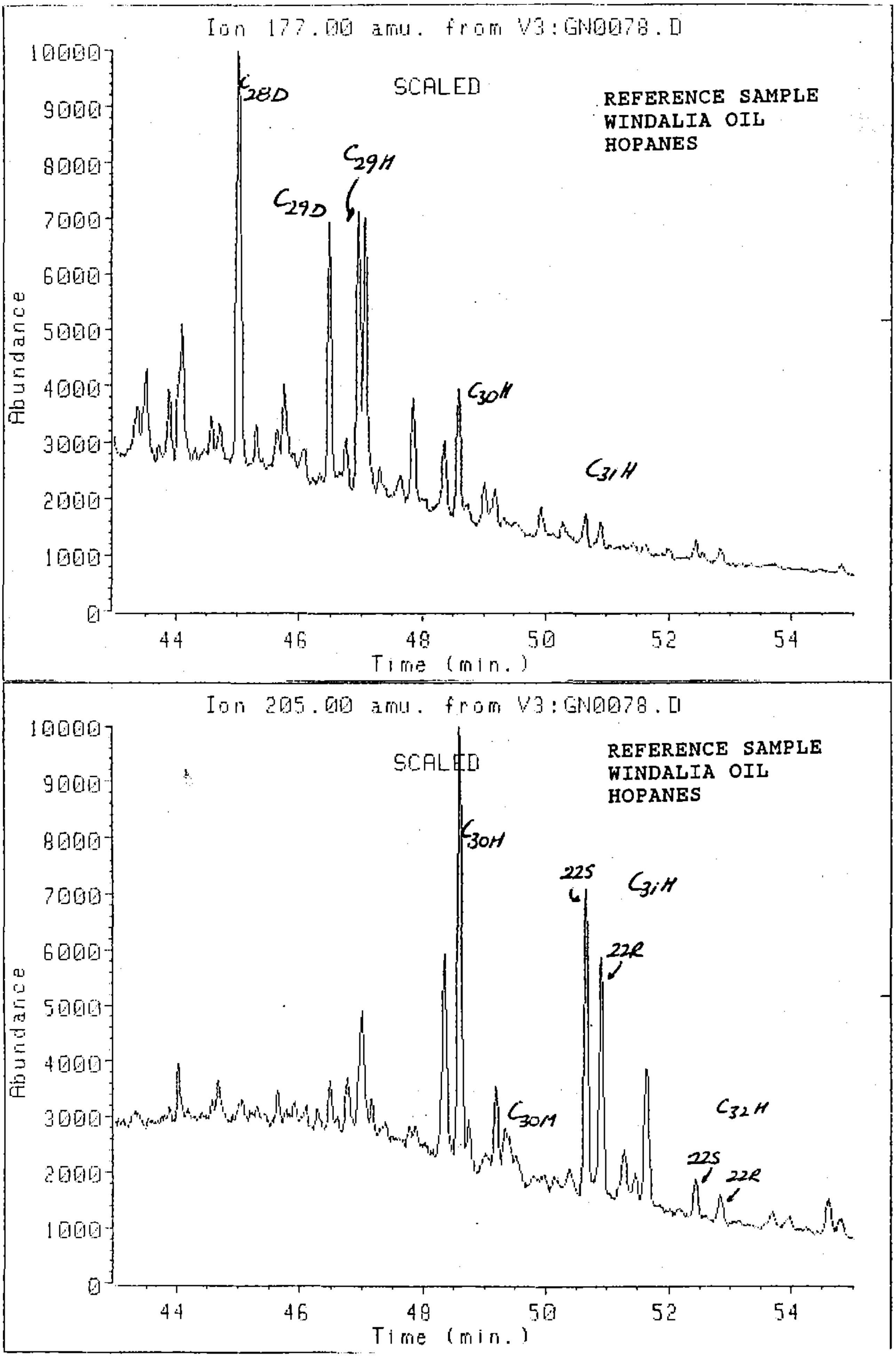


FIGURE 27A. MASS FRAGMENTOGRAM FOR M/Z 177 (C_{29} HOPANES PLUS DEMETHYLATED HOPANES) IN REFERENCE SAMPLE WINDALIA OIL.

FIGURE 27B. MASS FRAGMENTOGRAM FOR M/Z 205 (C_{31} HOPANES) FOR REFERENCE SAMPLE WINDALIA OIL.

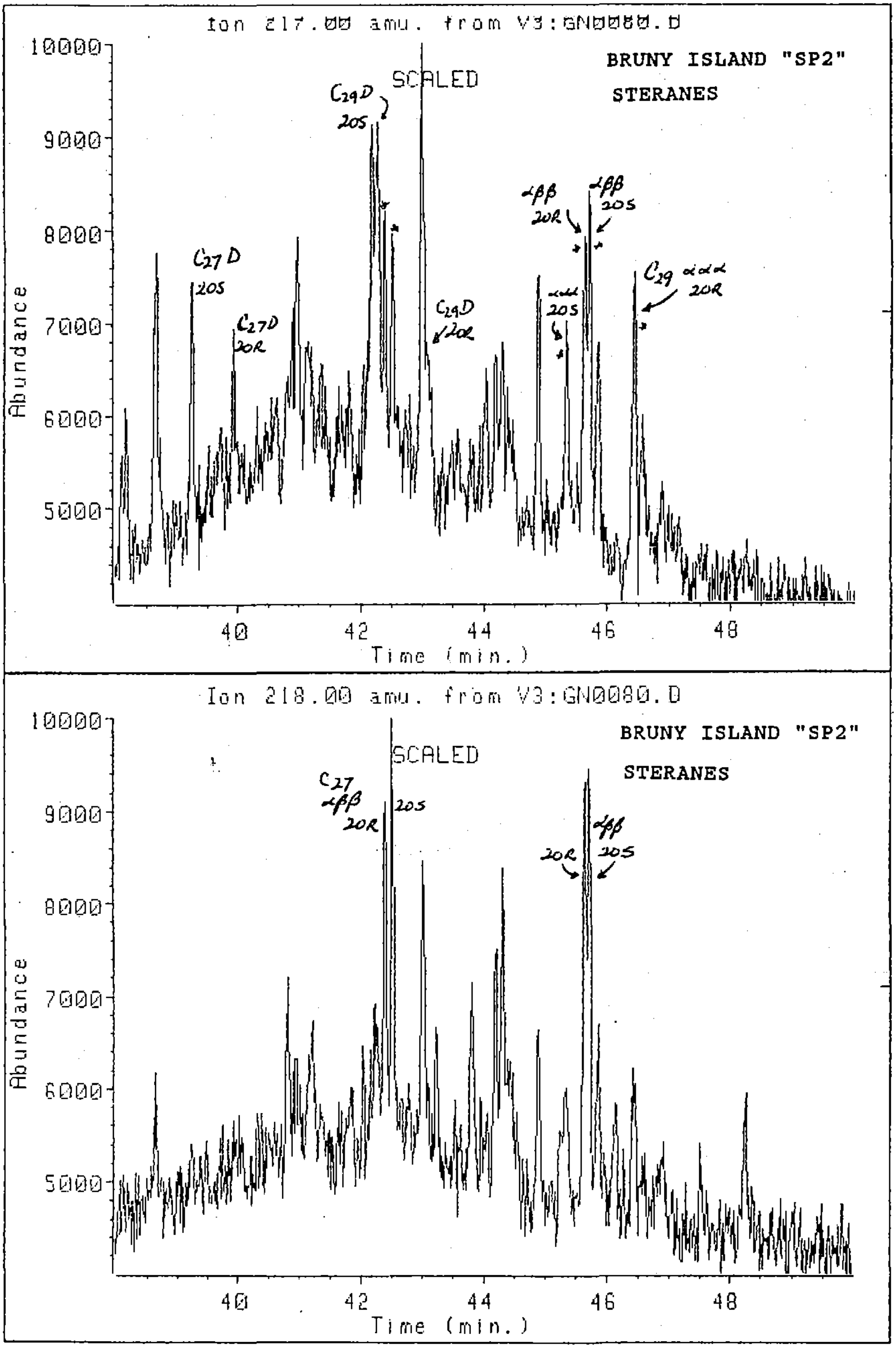


FIGURE 28. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{27} - C_{30} STERANES) IN BRUNY ISLAND SAMPLE "SP2".

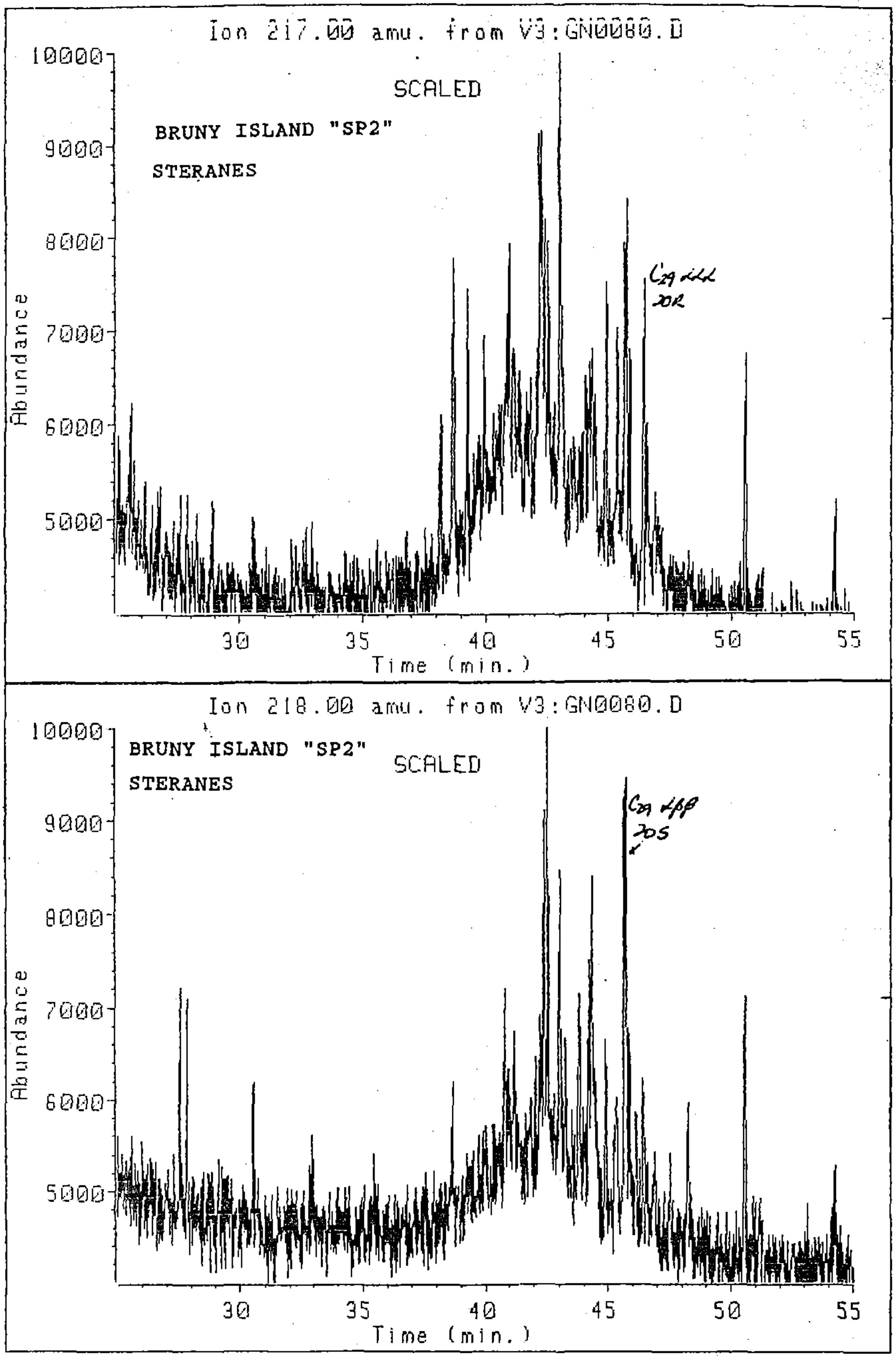


FIGURE 29. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{20} - C_{30}

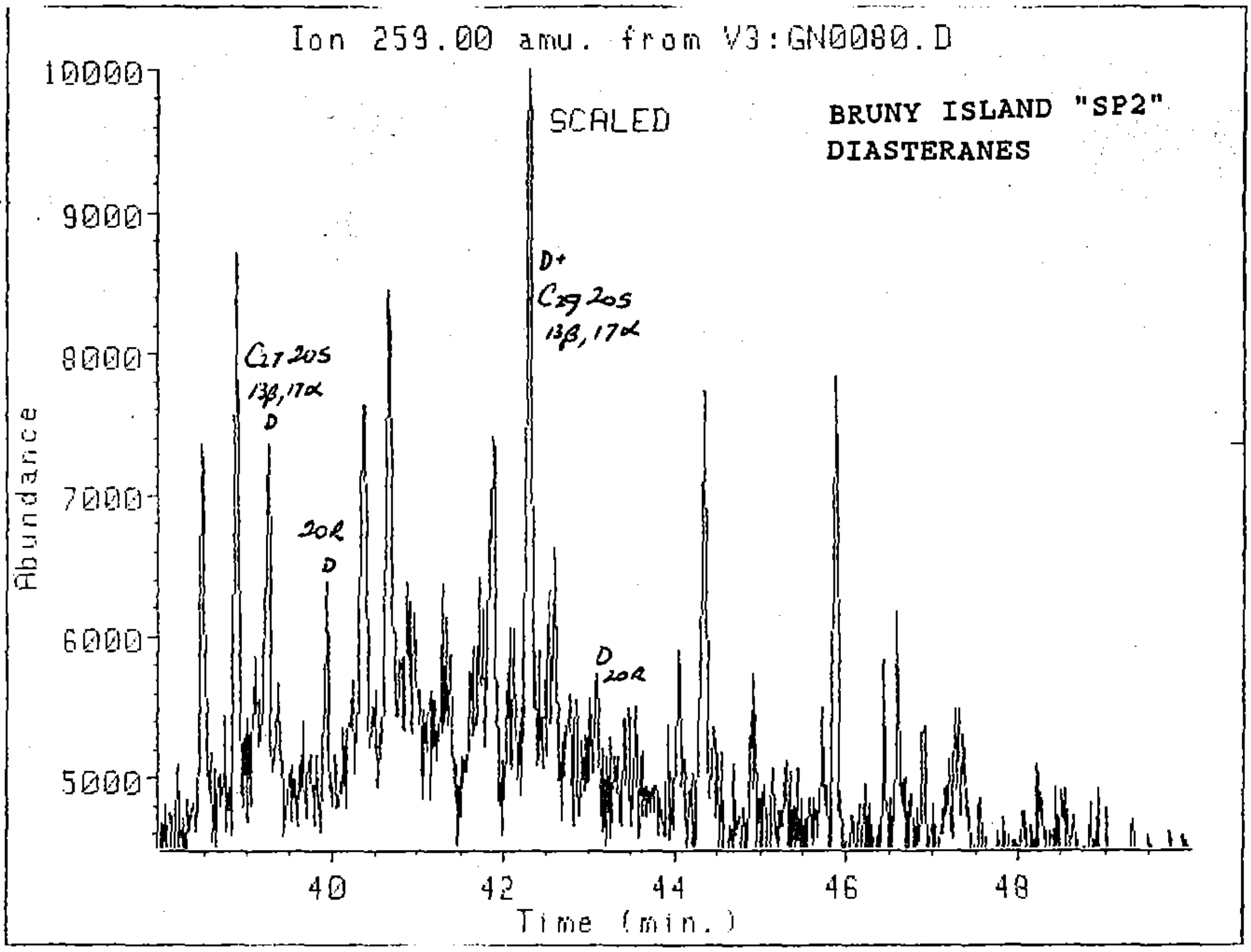


FIGURE 30. MASS FRAGMENTOGRAM FOR M/Z 259 (DIASTERANES) IN BRUNY ISLAND SAMPLE "SP2".

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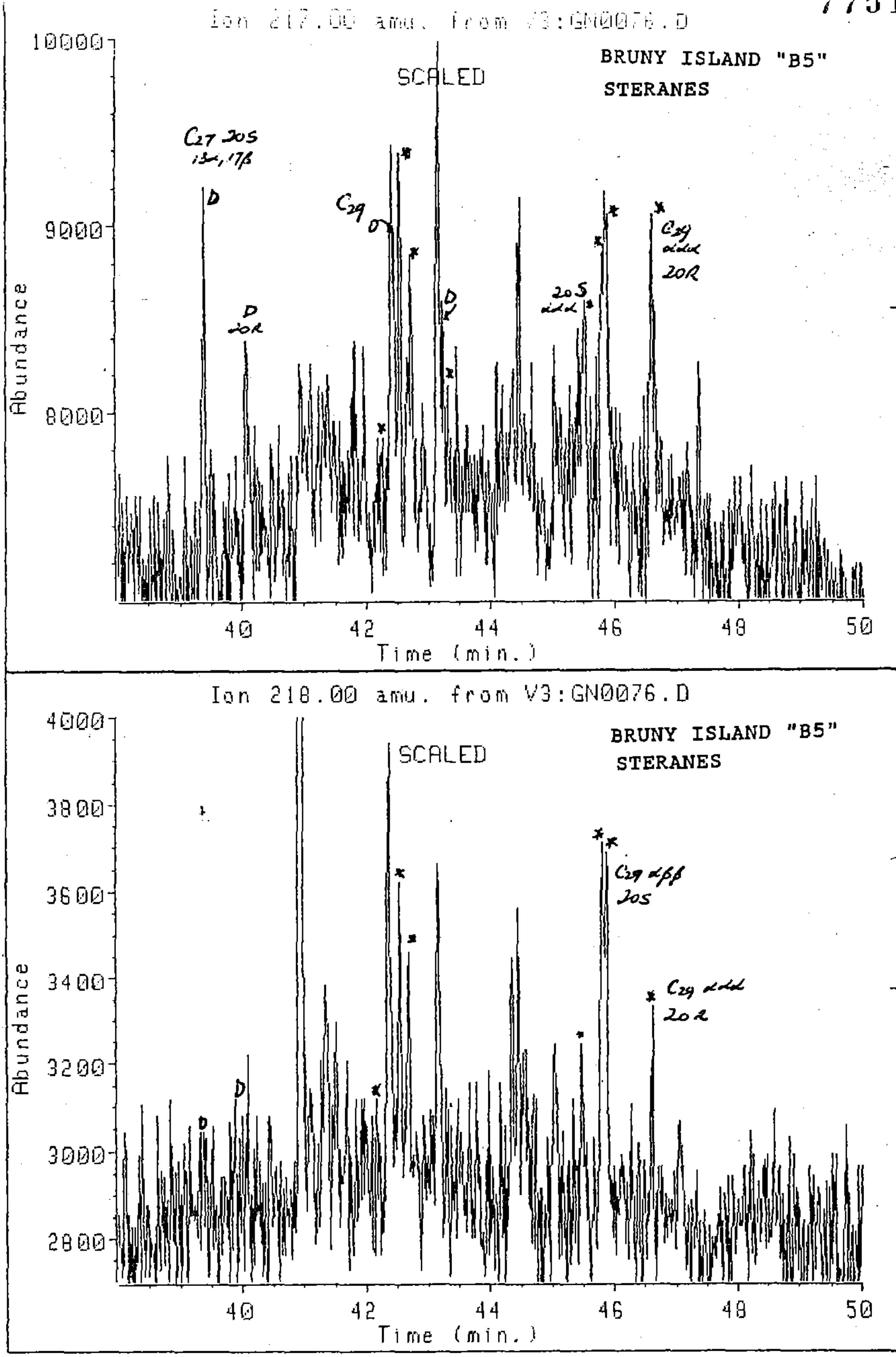

FIGURE 31. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{27} – C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B5".

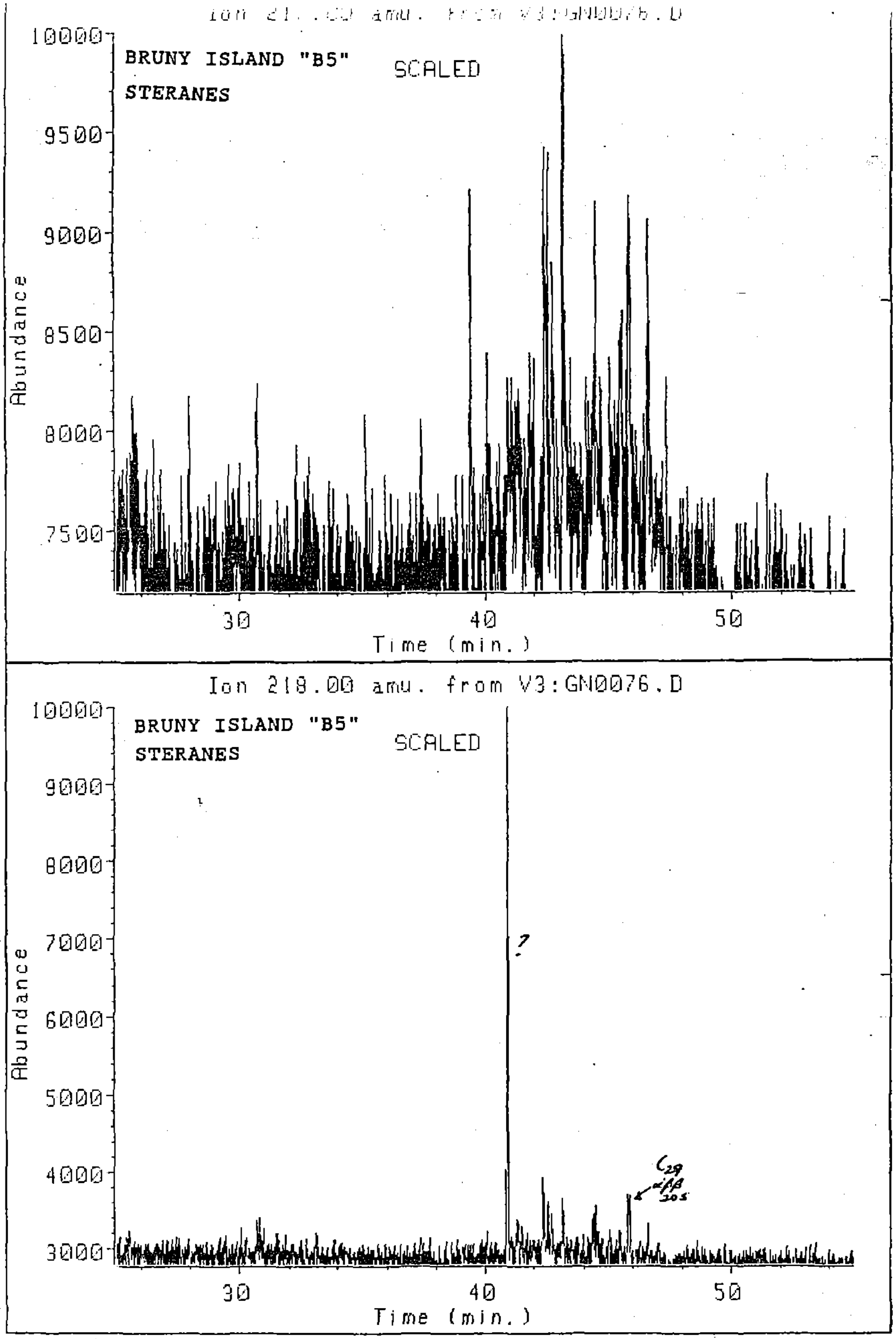

FIGURE 32. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{20} - C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B5".

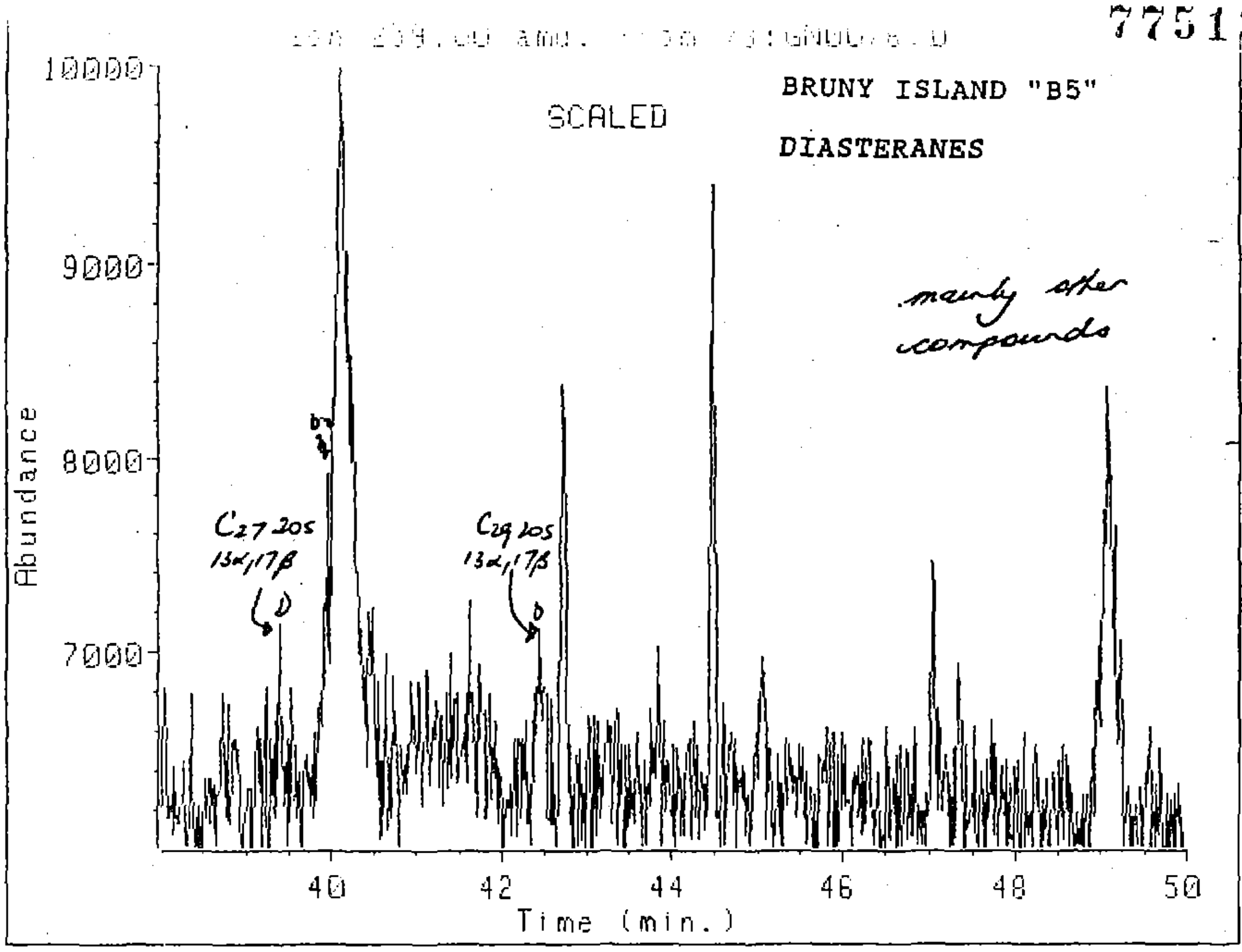

FIGURE 33. MASS FRAGMENTOGRAM FOR M/Z 259 (DIASTERANES) IN BRUNY ISLAND SAMPLE "B5".

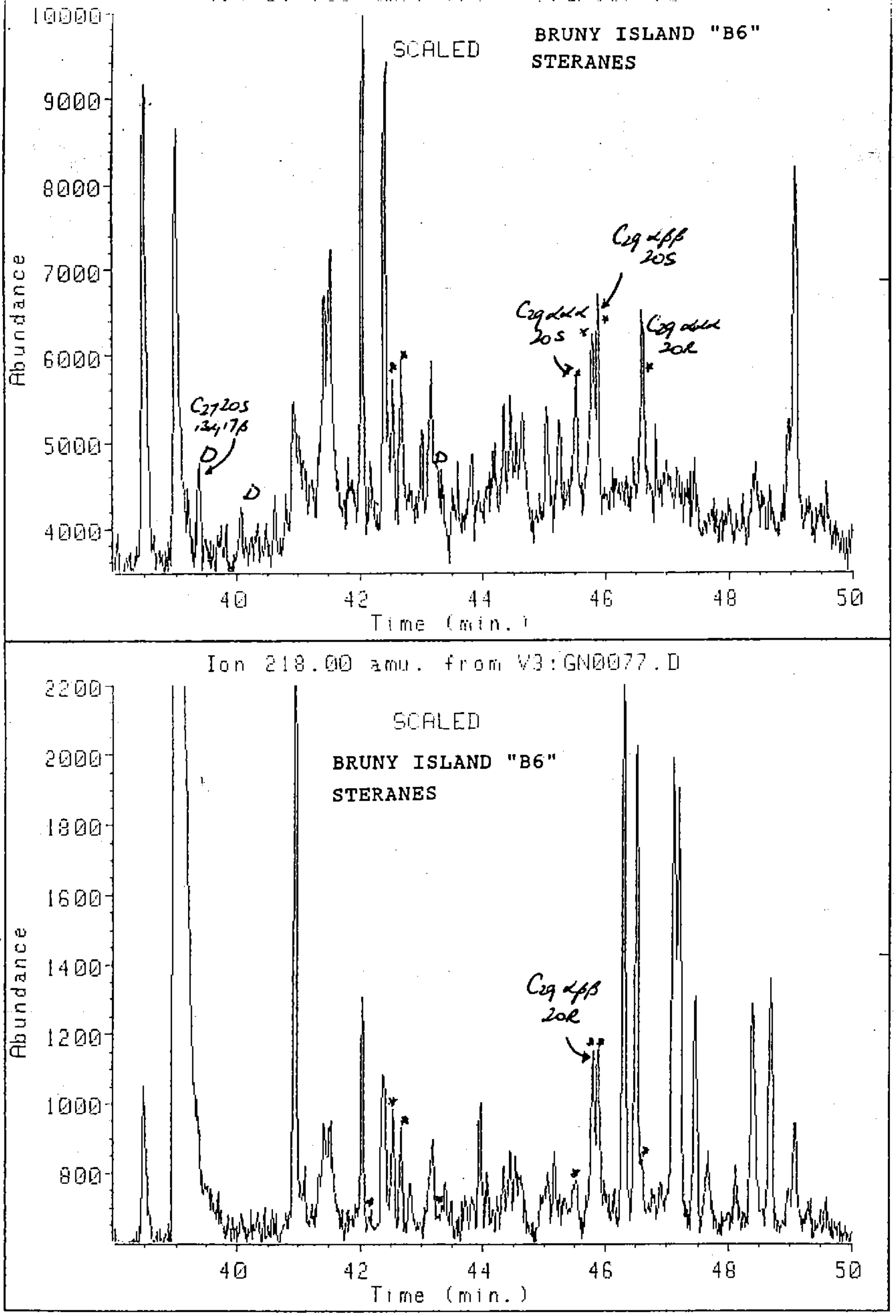

FIGURE 34. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{27} - C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B6".

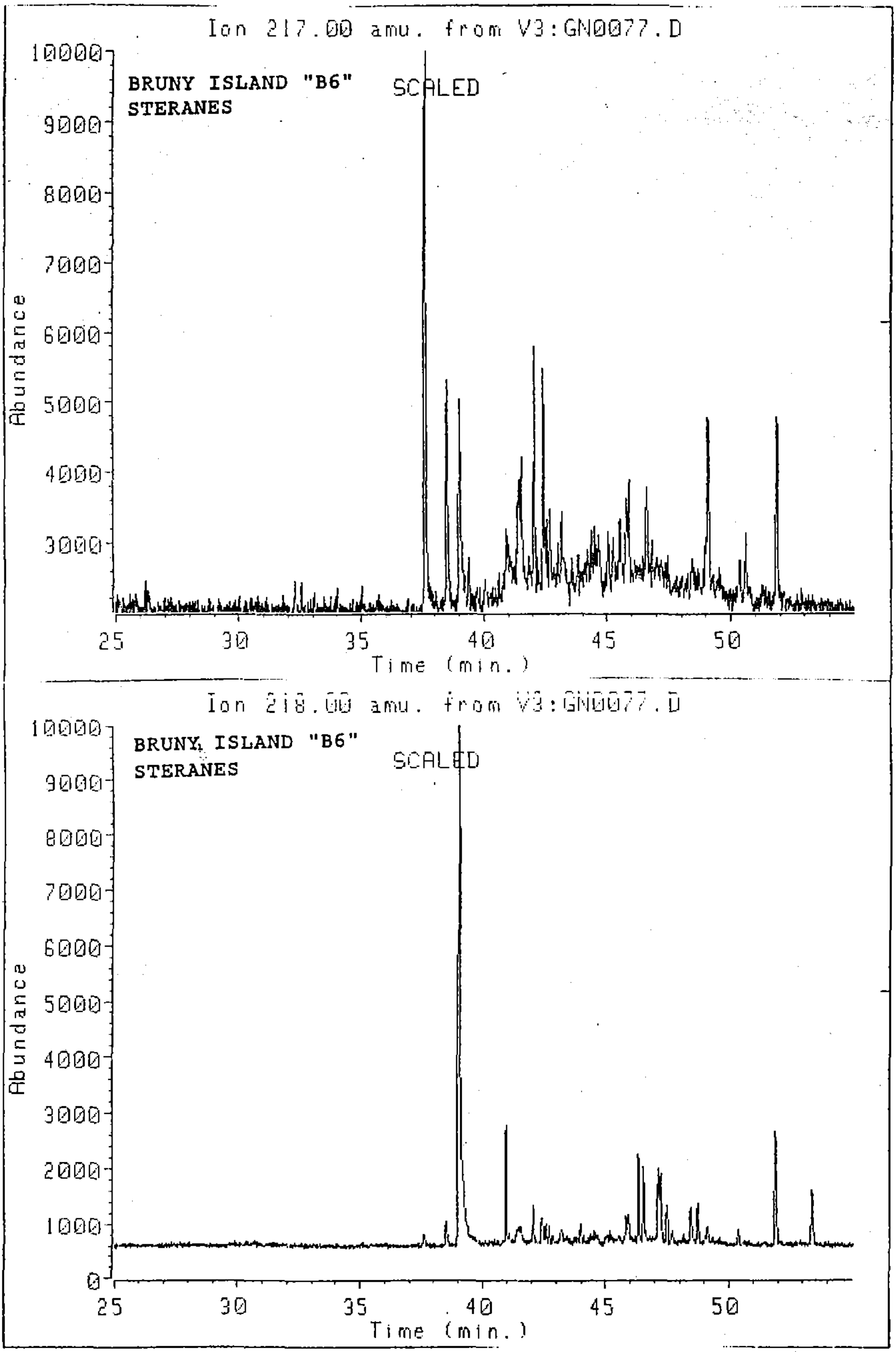

FIGURE 35. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{20} – C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B6".

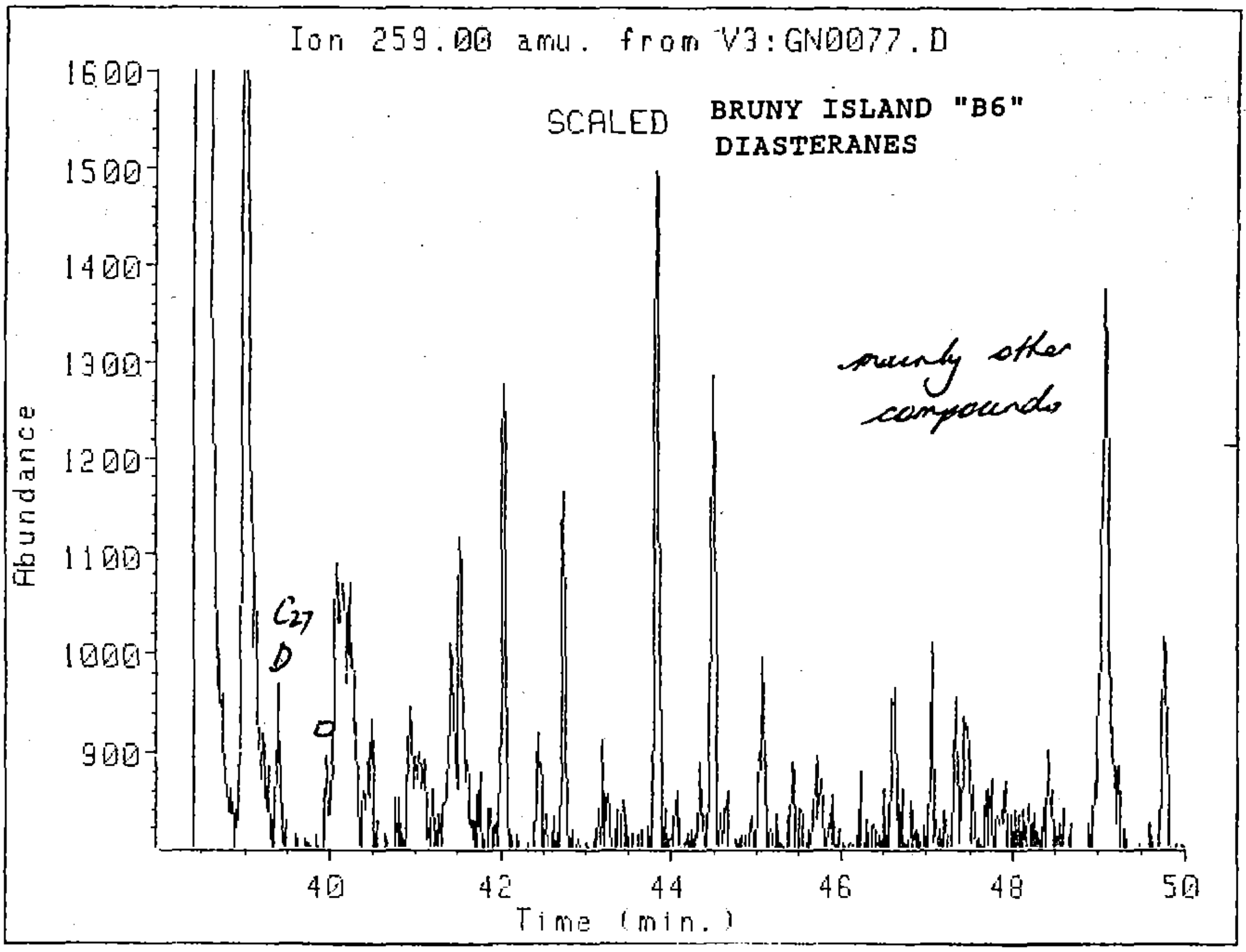

FIGURE 36. MASS FRAGMENTOGRAM FOR M/Z 259 (DIASTERANES) IN BRUNY ISLAND SAMPLE "B6".

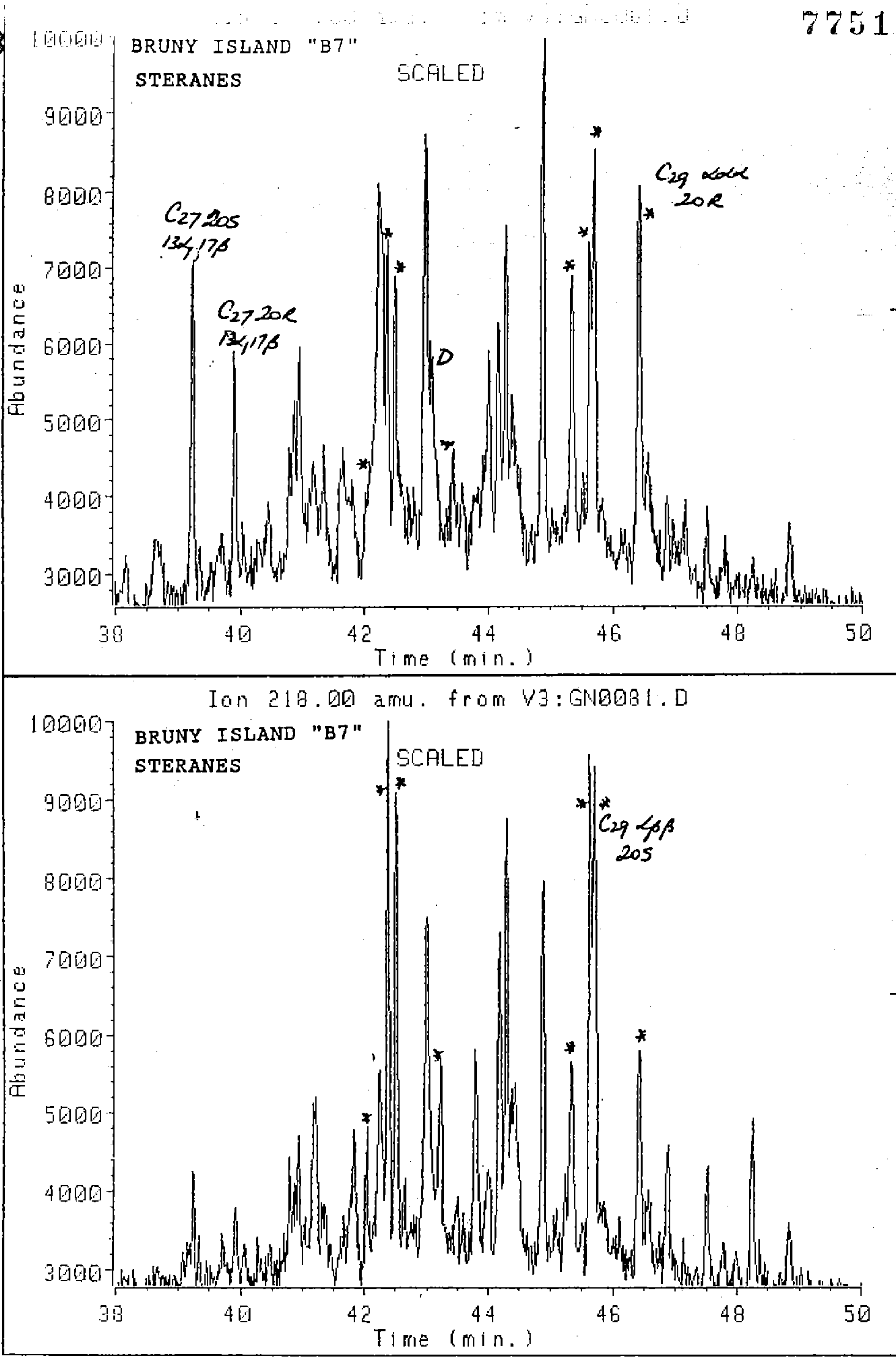

FIGURE 37. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{27} - C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B7".

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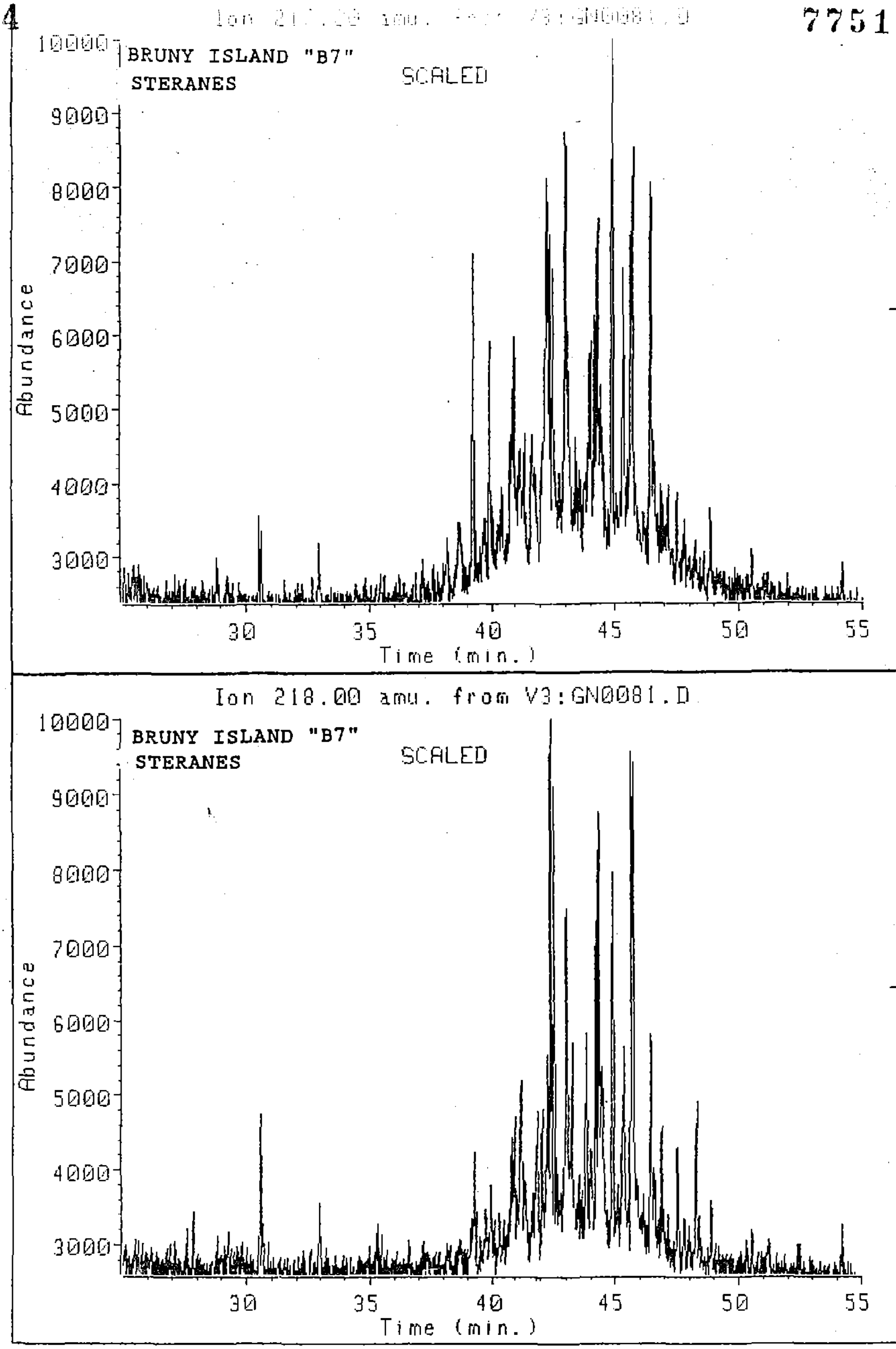

FIGURE 38. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{20} - C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B7".

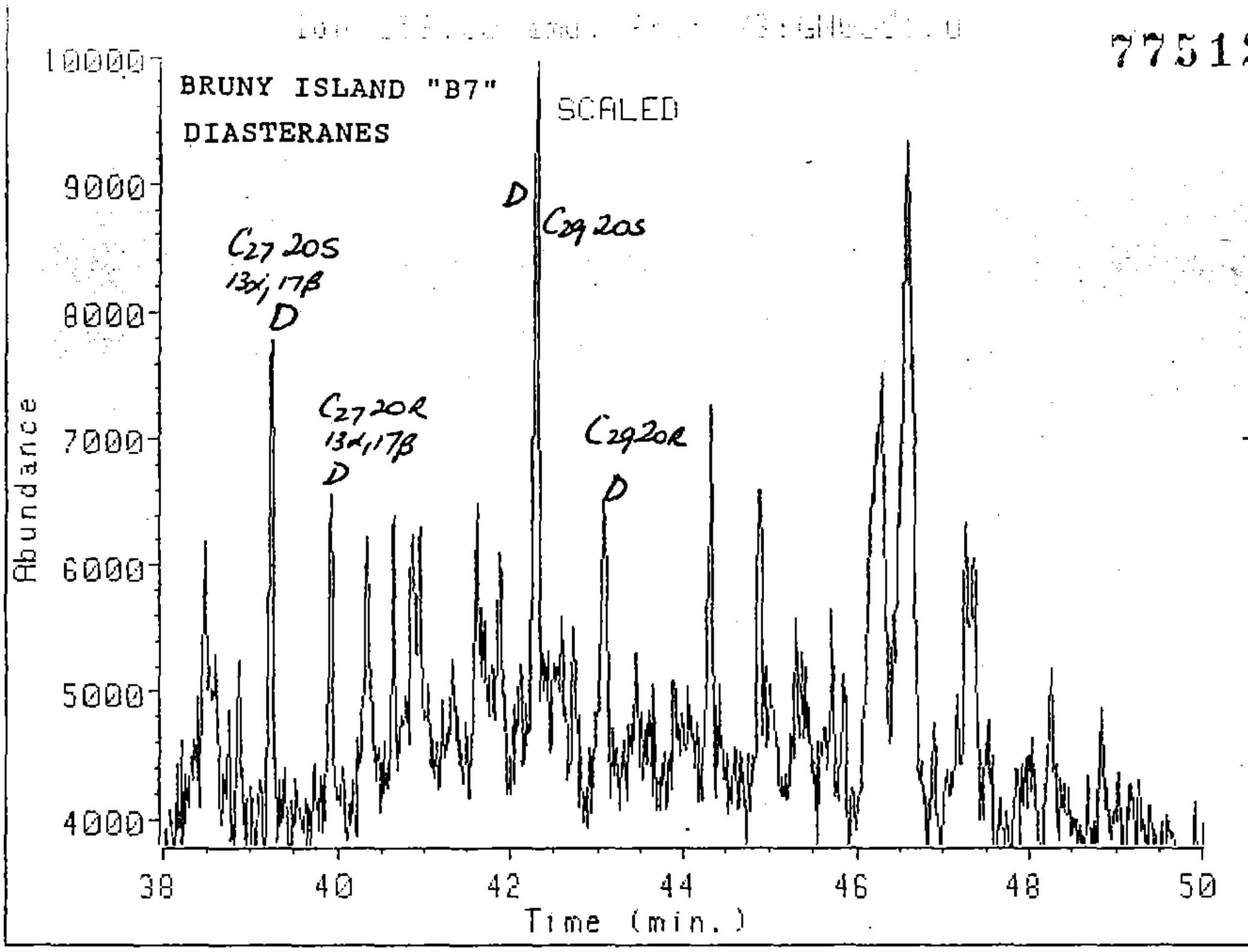

FIGURE 39. MASS FRAGMENTOGRAM FOR M/Z 259 (DIASTERANES) IN BRUNY ISLAND SAMPLE "B7".

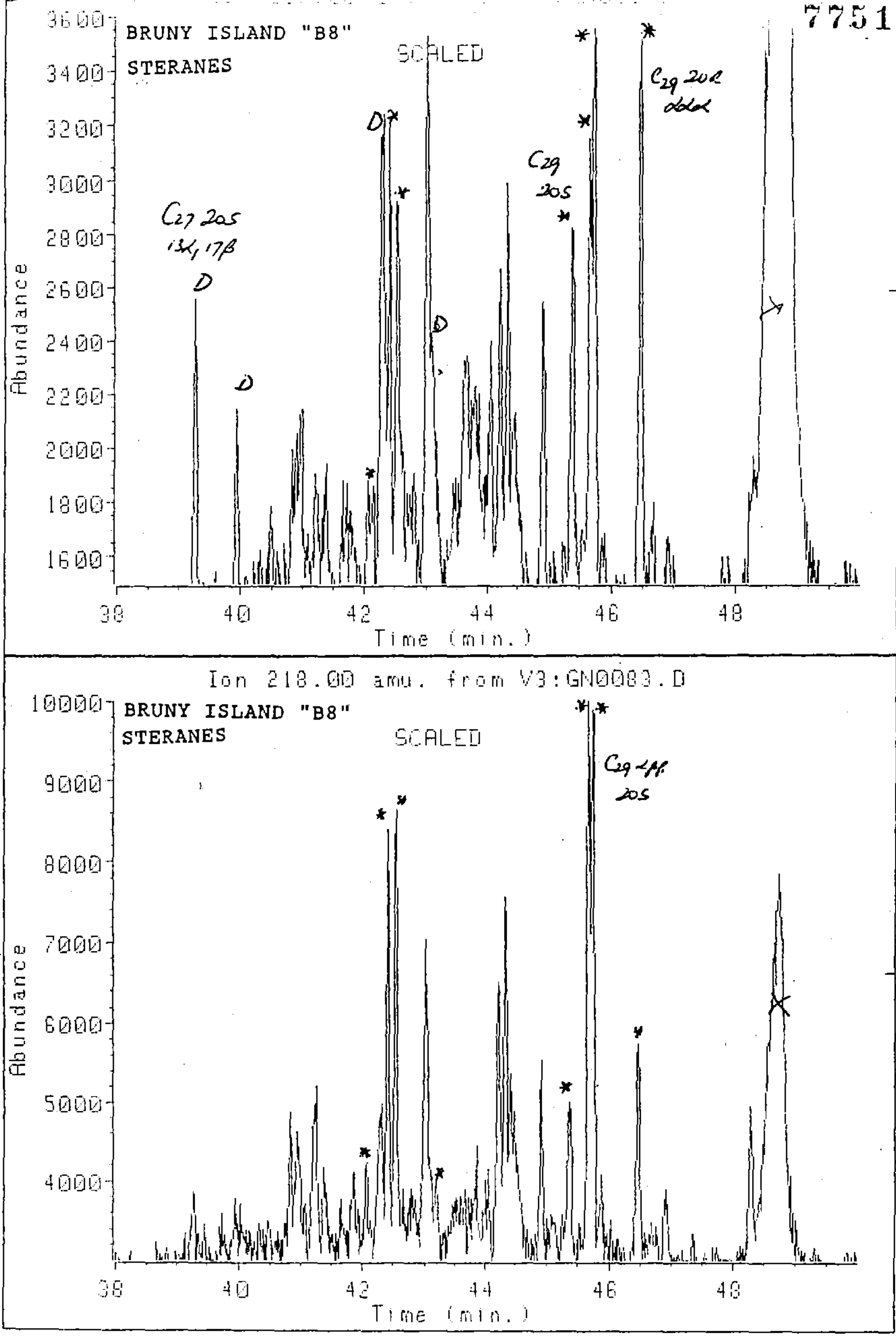

FIGURE 40. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{27} - C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B8".

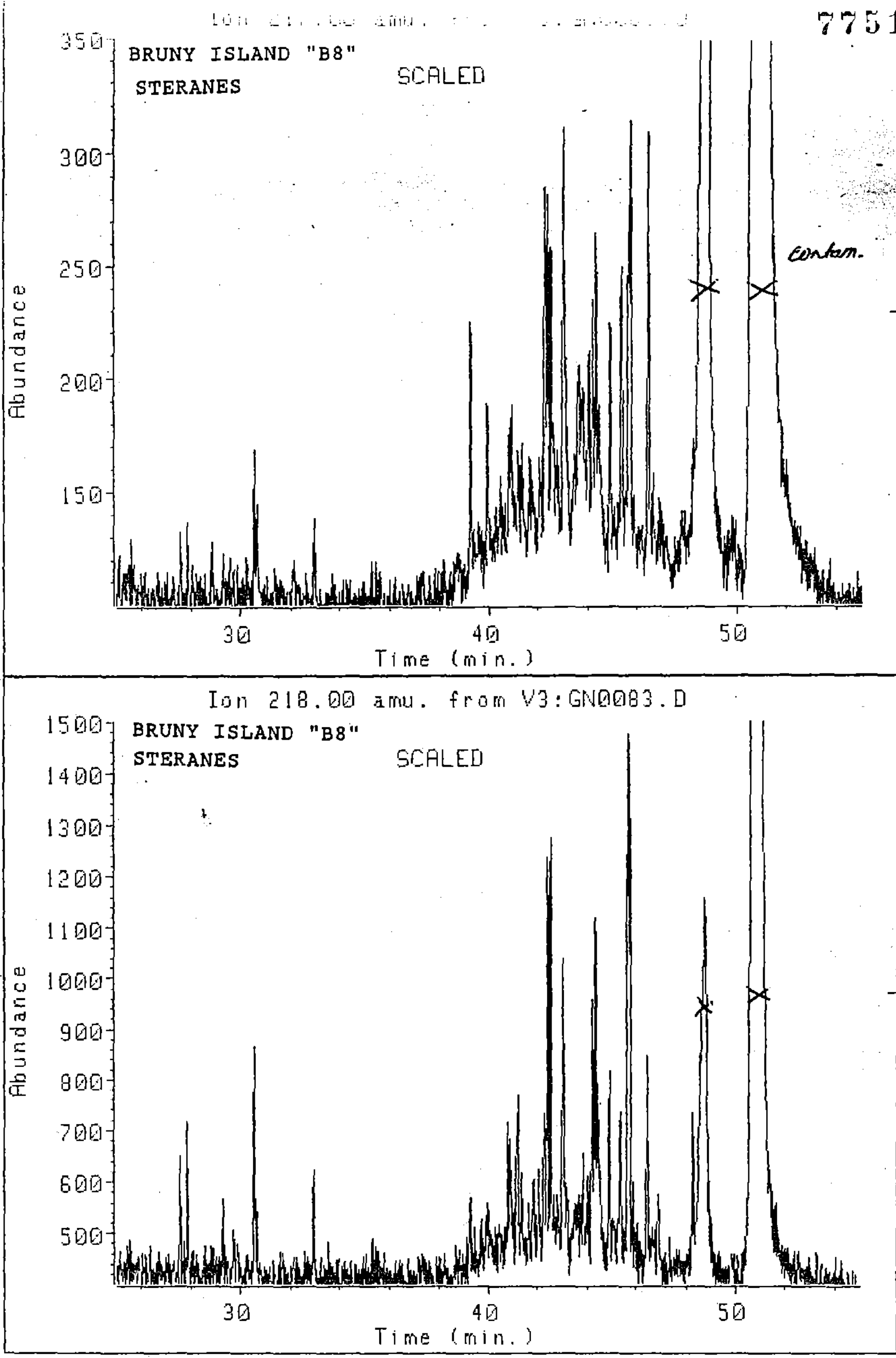

FIGURE 41. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{20} - C_{30} STERANES) IN BRUNY ISLAND SAMPLE "B8".

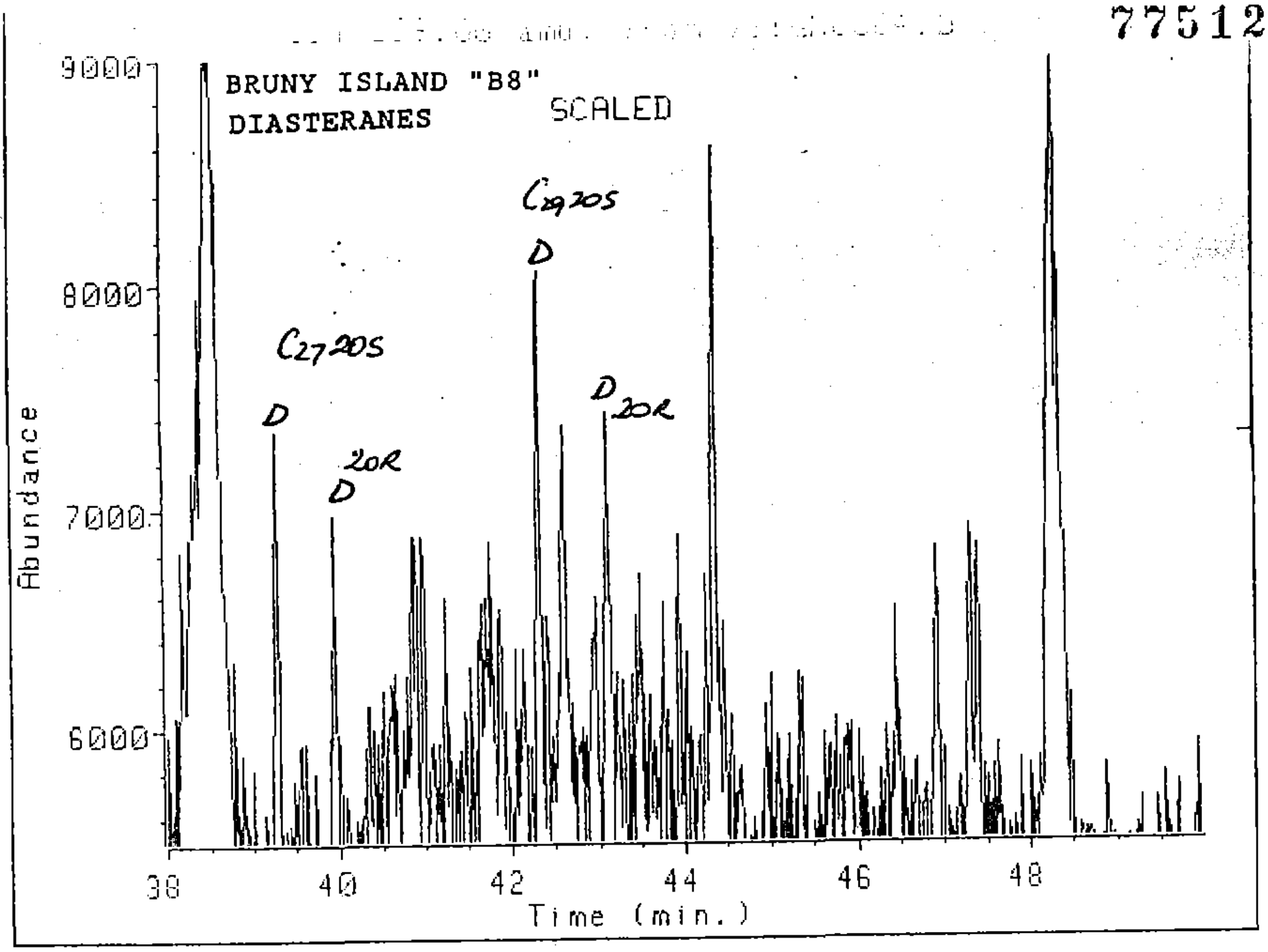

FIGURE 42. MASS FRAGMENTOGRAM FOR M/Z 259 (DIASTERANES) IN BRUNY ISLAND SAMPLE "B8".

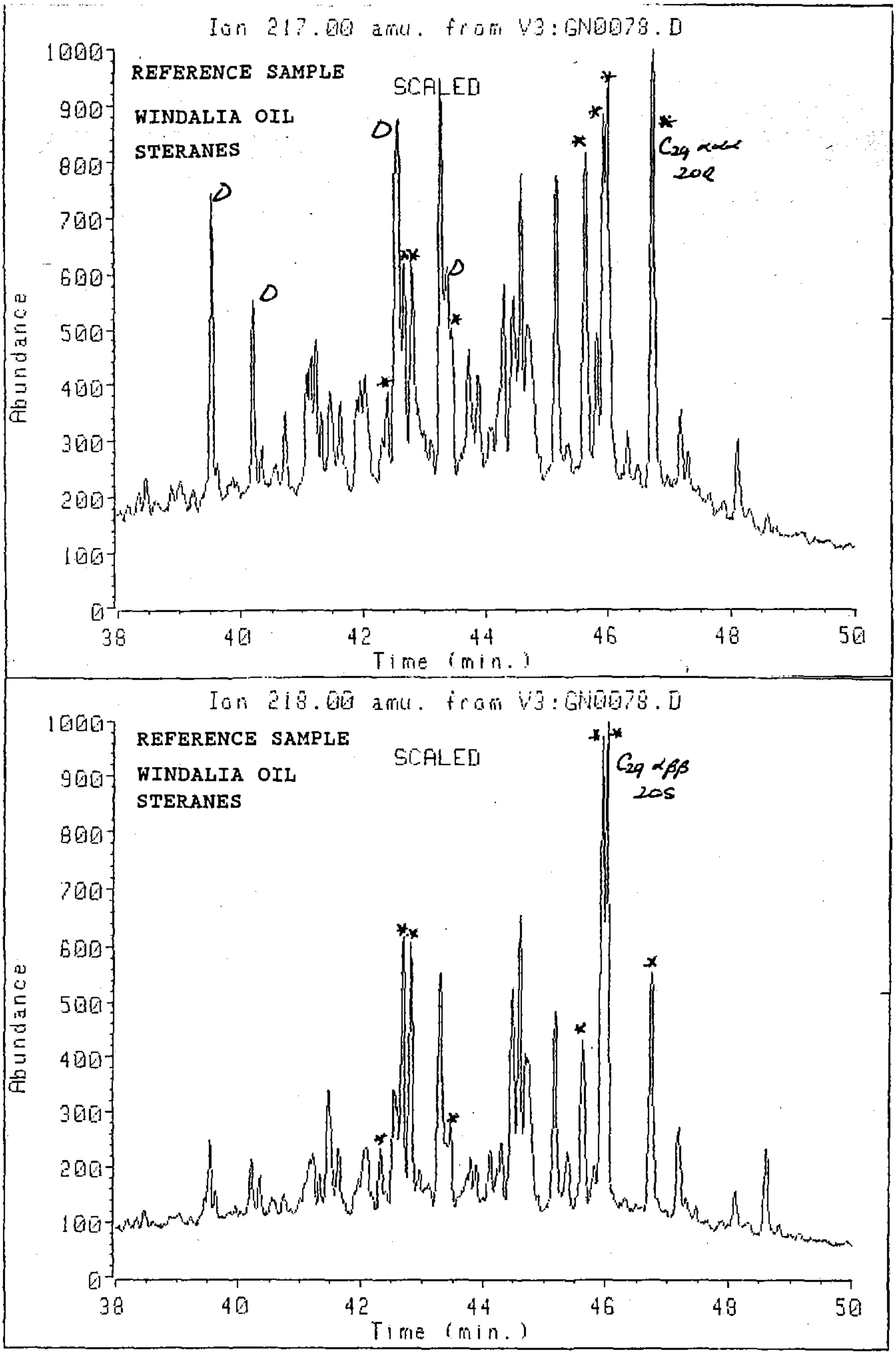

FIGURE 43. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{27} - C_{30} STERANES) IN REFERENCE SAMPLE WINDALIA OIL.

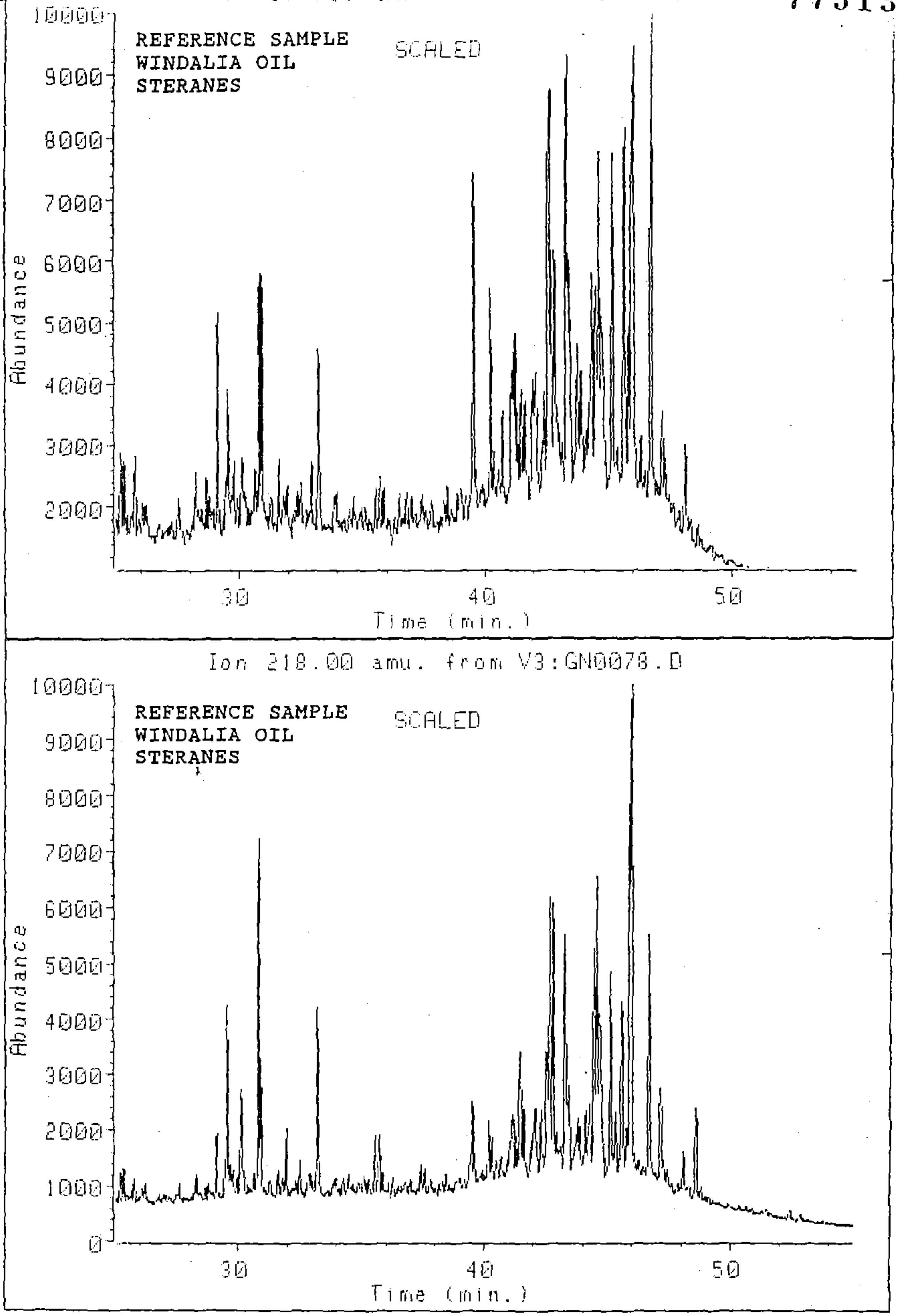

FIGURE 44. MASS FRAGMENTOGRAMS FOR M/Z 217 AND 218 (C_{20} - C_{30} STERANES) IN REFERENCE SAMPLE WINDALIA OIL.

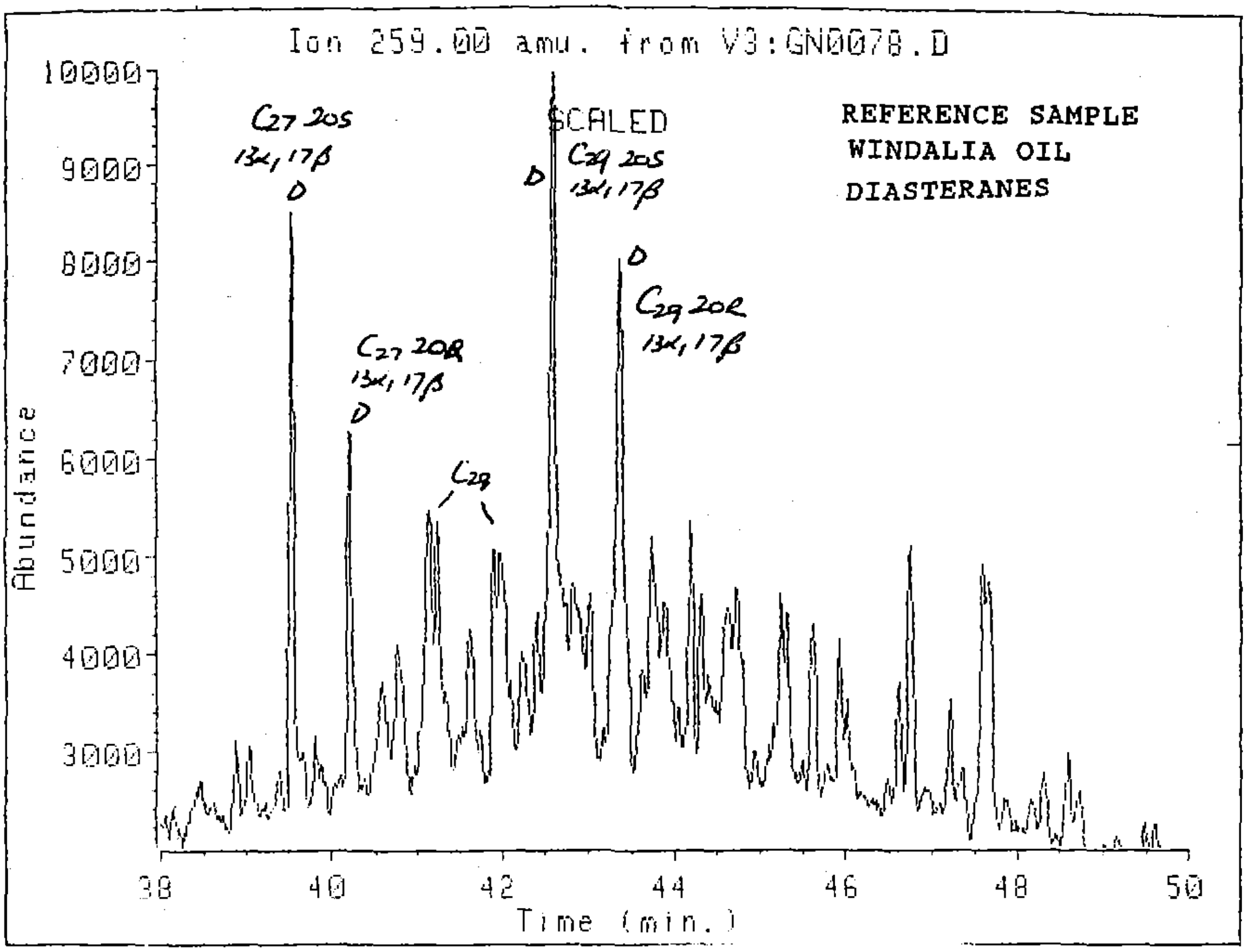

FIGURE 45. MASS FRAGMENTOGRAM FOR M/Z 259 (DIASTERANES) IN REFERENCE SAMPLE WINDALIA OIL.

APPENDIX 4

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CONGA OIL PTY. LTD.

RECORD OF INTERVIEWS AND

SAMPLE SITE INFORMATION

BRUNY ISLAND OIL SEEP SEARCH

K. MORRISON

January 1988

OIL EXPLORATION ON BRUNY ISLAND

RECORD OF INFORMATION OBTAINED DURING INTERVIEWS WITH PAST AND PRESENT BRUNY RESIDENTS

INRODUCTION

In June 1987 Conga Oil Pty. Ltd. commenced a programme of sampling areas on Bruny Island where oil seeps had been reported in the past. Several of the samples have been shown to contain trace amounts of petrogenic hydrocarbons and the work is continuing in an attempt to match these samples to probable source rocks. The locations of the samples taken during the 1987 programme were largely based on information from past and present residents of Bruny Island with knowledge of, and interest in, oil seeps and the two oil exploration bore holes which were sunk on North Bruny Island circa 1912 and circa 1929.

This report is a collection of notes in chronological order recording information gained during interviews with several people with either direct involvement in the past oil exploration, or with information pertaining to the drilling and/or reported seeps. Some of these stories are anecdotal and some of the information is ambiguous, however it is necessary to record this information as a useful contribution to both the current oil exploration activities of Conga Oil in the area and also to the history of Bruny Island. In addition to recording this information the report also describes the sites which were sampled by Conga Oil. Sample sites can be located on Tasmap 1:100,000 D'Entrecasteaux and Derwent sheets. The results of the sampling programme are recorded in reports to Conga Oil from Dr J. Volkam, CSIRO (October, 1987) and by K.C. Morrison Pty. Ltd. (November, 1987).

On **June 15, 1987** an excursion to Bruny Island, Cradoc and Crabtree by M. Bendall, D. Leaman and K. Morrison examined several sites where oil seeps had been reported in the past or where M. Bendall and D. Leaman had some evidence of possible seeps.

Johnsons Well (531500mE 5216800mN) is located some 500 metres east of Smootheys Point on the south west coast of North Bruny, and is the site of the most convincing of the early reported oil seeps (see McIntosh Reid's 1929 Mines Department Annual Report). It is also the location of the second exploration borehole on Bruny Island drilled circa 1929-1930. and the location of the sample taken by M. Bendall in 1986 and shown by Analabs to contain hydrocarbons. At the time of drilling, the property was owned by a Mr (Joseph ?) Johnson who lived in the house which still exists at Smootheys Point. The oil prospect was discovered in a water well which now exists as a small dam. The borehole collar site is approximately 35 metres north of this dam. The property is now owned by by Mr Ross Denne, Barnes Bay, Bruny Island (002 606204).

On June 15 1987, two samples were taken from the dam at Johnsons well. **SP1** was a sample of scum from the surface water of the dam and SP2 was a sample of scum from the dam floor immediately above the water mark.

An area behind the Adventure Bay Caravan Park, in the tidal reaches of Captain Cook Creek (526500mE 5198500mN) where M. Bendall knew of reported oil scum on the water surface, was examined. Nothing considered worthy of sampling was observed.

At Balfes Hill, 3 km north of Cygnet a location known to D. Leaman as a possible oil seep site was sampled at approximately 505,500mE 5,224,900mN in a small creek draining Balfes Hill. Sample **C1** consisted of scum taken from the surface of water in several small puddles adjacent to this creek.

At Crabtree, in the southern foothills of the Wellington Range, an area located at approximately 506,600mE 5,244,300mN was inspected. M. Bendall suspected oil seeps in drains and farm dams at this site. No material considered worthy of sampling was observed.

Between **June 30** and **July 22** several people were interviewed by phone.

Mr Vince Oakford, Bruny Island Council Clerk (002 931139) had no knowledge of seeps or oil exploration but suggested the previous clerk (40 years at the job) Mr Barkley Smith and council employee, Mrs Janice Higgins. Mr Smith had no information beyond the general knowledge of the two boreholes and various reported seeps spanning several decades. He suggested that Mr Guy Elliston may have additional information. Mr Elliston (002 396377), together with his son, Robert Elliston, own the property at the southern end of north Bruny on which the airstrip and the earlier of the two boreholes (Andrews Bore) are located. Robert Elliston can be contacted at the Bruny Island Health Centre, Alonnah, on (002) 931143. Guy Elliston was very interested in the possibility of oil being discovered on his property. He said there was a strange smell and a whitish semi-solid material in a water hole approximately 200 metres east of the Andrews Bore site. He believed the borehole had been sunk circa 1910 and described where the site could be found relative to the airstrip. He was keen for Conga Oil to sample on his property and suggested Mr Don Davis and Mr Ross Denne as long time Bruny residents who should have knowledge of the previous drilling.

The other contact at the Bruny Island Council, Mrs Janice Higgins recalled evidence of oil at Killora, in the north east of North Bruny, in the garden and in a creek adjacent to her mother-in-law's house. Mrs Higgins senior (002 283659) confirmed that often, particularly in the summer, there was an oily smell in their garden and that carrots from the garden sometimes needed cleaning to reduce the oily, diesel-like smell. There was also, again usually during the summer, an oily scum seen and smelt on a creek near the house. (This creek flows some 50 metres north of the house, into Rat Bay, south of Killora).

A phone call to Mr Don Davis (002 931187) revealed that he was "over 80" years old and had been about 8 years old when Andrews Bore was sunk near The Big Lagoon. Mr Davis recalls the steam-driven plant being shipped to Smootheys Point and dragged by bullocks to the drill site. He estimated that drilling lasted about 1 year and that the hole was abandoned at about 400 ft. He did not know whether any oil was encountered and had never seen a seep, although he had heard many other people refer to them. He believed that the bitumen-like material found on the coast at Cape Queen Elizabeth was the most likely genuine seep and that most of the others, including Johnsons Well, were "peat water" mistaken for oil.

Mr Ross Denne was contacted and arrangements were made to meet him at Smootheys Point on July 24.

On **July 23** Mr Colin Hanson (002 931124) of Adventure Bay was contacted concerning a report passed on to M. Bendall by a geology student at the University of Tasmania. The student recalled seeing scum on the water in cattle hoof impressions on Hanson's property and scum in Hanson's toilet. Mr Hanson revealed that he did not own cattle or any property (only a normal quarter acre block) but that his toilet water was permanently discoloured because he used dam water, conserving tank water for drinking and washing.

It was concluded that the sampling of materials in Mr Hanson's toilet bowl could not be justified.

On **July 24** the Johnsons well borehole site was inspected with Ross Denne. Rusted casing approximately 3 inch in diameter, is exposed in the collar. Mr Denne believed that the rig had been largely home made by a syndicate of locals, had been driven by a petrol engine and that the hole had been abandoned at about 170 feet, after attempts to install and cement casing had failed. The equipment had been left at the site where the hole was abandoned. Mr Denne had had no experience with seeps but knew of the reports, in particular the Cape Queen Elizabeth bitumen. He new of a neighbour, Mr Allan Bain, who had mentioned a possible oil seep on his property in recent times.

An inspection of Mr Bain's site, together with Mr Bain, revealed water with a metallic blue scum seeping from eucalypt bark and off-cuts from a small saw mill operated by Mr Bain (531,400mE 5,215,400mN). No sample was taken.

Samples were taken on July 24 at the following sites:

Sample No. **84** (531,500mE 5,216,900mN). Scum on the top of Hazell Bros. dam, approximately 100 metres north of Johnsons Well. The dam is excavated into Permian marine lutites, some of which are dark coloured and possibly carbonaceous.

Sample No. **85** (530,000mE 5,212,500mN). Scum and whitish residue in a small waterhole in marshy country adjacent to The Big Lagoon. The water hole contained heavy algal growth and smelt strongly of sulphur.

Sample No. **86** (526,200mE 5,228,250mN). Scum on the creek and beach adjacent to the new abandoned house at Killora, previously occupied by Mrs Higgins.

During the sampling of B5, the collar site and some remains of Andrews Bore were located at approximately 531,000mE 5,212,500mN. When sampling **B6**, the probable previous garden site mentioned by Mrs Higgins was located however no evidence of smell or residue in the soil was detected.

On **August 20** another field trip to Bruny Island was conducted to, firstly, resample the original M. Bendall 1986 sample at Johnsons Well (new sample No. **B7**) and secondly, to search for evidence of the reported bituminous material in dolerite joint cracks between Miles Beach and Cape Queen Elizabeth. The coast between Miles Beach and Cape Queen Elizabeth was walked and although cracks in the dolerite are abundant, no evidence of the bituminous material was observed. A scum on the surface of Miles Creek was sampled where the creek flows over Miles Beach at approximately 533,700mE 5,212,200mN (Sample No. **B8**). Miles Creek drains an area of Permian outcrop on the western side of a major N-S fault contact between the Permian and the Jurassic dolerite. Reported oil seeps in Miles Creek were described by McIntosh-Reid in 1929.

On **September 15** phone contact was made with Rex and Collin Calvert, two brothers whose father worked supervisor on the Jonsons Well borehole around 1929 - 1930 and who both had memories of oily water being recovered from the hole. Collin Calvert (003 273967), the elder brother, remembers helping his father on many weekends at the drill site. His father was involved with th drilling for approximately 9 months, resigning after prolonged trouble in casing the hole and cementing the casing. Both Collin and Rex stated that thick oil shows were encountered in the drilling returns at about 90 feet and Collin recalls bringing containers from the family orchard to collect the oily water. Collin also stated that there were stories of oil being encountered in the earlier well at The Big Lagoon. 12.

On **December 12** Mrs Bev Davis (002 931211) was interviewed at the Medical Centre, Alonnah (002 931143) where she works. Mrs Davis is compiling a book, *Guide to Bruny Island History* to be published in the Bicentennial Year. Some of the information she has collected from newspapers in the State Archives pertained to coal and oil exploration. She had a copy of a book, *Bruny Island - A Regional Planning Study* published by the T.C.A.E. in 1980. The book contains photos of Andrews Bore and mentions that the hole was in progress during World War 1, a little later than the previous estimates of the age of Andrews Bore. On page 17 of this book reference is made to the Johnsons Well drilling in 1930 and the following quote appears. "Old timers remember the story with major variations but all are quite certain that bottles of oil were taken from the well." The article also states that the investigator of the project, a Mr Black, disappeared from the scene and that the locals still remember the debts accrued by the project. A copy of this book has been acquired by Conga Oil.

Mrs Davis had old newspaper information suggesting that both exploration wells relied largely on private funding by local syndicates. She also remembered being told by someone during her investigations that a photo of Mr Joseph Johnson holding a bucket of oil had appeared in either *The Mercury* or *The Tasmanian Mail* around 1930.

APPENDIX 5

PROBABILISTIC EARTHQUAKE RISK MAPS OF TASMANIA

Marion O. Michael-Leiba & Brian A. Gaull (BMR)

ABSTRACT

New earthquake risk maps of Tasmania have been prepared depicting risk by contours of peak ground velocity, acceleration and intensity with a 10 per cent probability of being exceeded in a 50 year period. The Cornell method (Cornell, 1968; McGuire, 1976; Basham and others, 1985) was used. The maps are based on seismicity up to 1984 and take into consideration the events of the 1883-1892 earthquake swarm east of Flinders Island and other historical data.

The earthquake process was assumed to be Poissonian, so foreshocks and aftershocks were eliminated before the magnitude-frequency recurrence relations were determined for the zones.

For this earthquake risk assessment, average eastern Australian background seismicity and attenuation for average site conditions were used.

The earthquake source zones most affecting the risk in the Tasmanian region are the 40°S Zone (West) and the Western Tasmanian Zone. The 40°S Zone (West) extends from east of Flinders and Cape Barren Islands into the Tasman Sea to 150.3°E. The 1883-1892 swarm appears to have occurred in this Zone, with at least one intensity-deduced Richter magnitude 6.0 - 7.0 event in each of the years 1884, 1885 and 1892. Consequently, the highest risk land areas are Flinders and Cape Barren Islands which lie predominantly between the $60mm.s^{-1}/0.6m.s^{-2}$ and $120mm.s^{-1}/1.2m.s^{-2}$ contours with the risk increasing to the east.

The Western Tasmanian zone includes western and northwestern Tasmania and seismicity off the west coast and in the vicinity of King Island. The largest event recorded in the zone was in 1880. It had an intensity-deduced Richter magnitude of 5.6. It occurred in southwest Tasmania and was felt with a maximum intensity of MMVI in southern Tasmania. The northern part of western Tasmania (enclosed by the 59 $mm.s^{-1}/0.55\ m.s^{-2}$ contour) is the second highest risk region. Queenstown is on the 58 $mm.s^{-1}/0.54\ m.s^{-2}$ contour (corresponding to an intensity of MMVI-VII with a 10 per cent chance of being exceeded in a 50 year period). Devonport, is on the 33 $mm.s^{-1}/0.31\ m.s^{-2}$ contour (intensity MMV-VI). At Hobart and Launceston, the values are 23 $mm.s^{-1}/0.21\ m.s^{-2}$ and 30 $mm.s^{-1}/0.29\ m.s^{-2}$ respectively, corresponding to a 10 per cent chance of an intensity MMIV-V being exceeded in a 50 year period.

The 100 year intensity expected at Launceston would be only MMIV-V. However, the observed maximum intensity reported there during the swarm was MMVII. Also, Launceston experienced MMV from a magnitude ML5.7 earthquake in the 40°S Zone (West) in 1946, and greater intensities than would be expected for an average site from other earthquakes. Thus it appears that site amplification of strong ground motion takes place in some parts of Launceston and should be considered when zoning for the Building Code.

The chief contributions to uncertainty in the estimates of earthquake risk are uncertainties in early earthquake locations and magnitudes, and in strong ground motion attenuation, for which accelerograph recordings and more Tasmanian isoseismal data are needed.

INTRODUCTION

The first seismic risk map of Tasmania was that of Underwood (1973). He produced contours of intensity at a 10-year return period based on 10.5 years of data.

McCue (1978) contoured the return periods of peak ground velocities of 50mms^{-1} and 100 mms^{-1} for the Tasmanian region.

The present zoning map (1978) adopted for inclusion in the Australian Building Code by the Standards Association of Australia is based on that of McEwin and others (1975) and Denham (1976). In it, the Tasmanian mainland is zone 0 and Flinders Island is zone A. As the available Tasmanian earthquake data have increased considerably since this map was drawn, it is an appropriate time to prepare new maps as part of the rezoning of the whole of Australia.

In this study, we have produced risk maps of Tasmania for the area 39 - 44°S, 142 - 150°E, using the Cornell methodology (Cornell, 1968; McGuire, 1976) as described by Basham and others (1985), and earthquake data from the BMR earthquake data file up to the end of 1984, Ripper (1963) and Michael-Leiba (in prep.).

The magnitudes of historic events from Michael-Leiba (in prep.) are designated MI. MI is an approximation to the Richter magnitude, ML. It is determined (Michael-Leiba, in prep.) by comparing the more reliable isoseismal radii, measured from an isoseismal map of the earthquake, with the average eastern Australian attenuation curves for various magnitudes (Gaull, Michael-Leiba and Rynn, in prep.).

METHOD

Seismic risk estimation using the Cornell (Cornell, 1968; McGuire, 1976; Basham and others, 1985) methodology requires the definition of:

1. earthquake source zones, each having its own magnitude-frequency recurrence relationship, mean focal depth, and maximum magnitude (which was chosen to be the maximum observed magnitude + 0.5, then rounded to the nearest 0.5 magnitude unit following Basham and others 1985);
2. background seismicity; and
3. attenuation of strong ground motion.

The McGuire (1976) computer program, as modified by Basham and others (1985), uses the attenuation and recurrence relations to numerically integrate contributions from the source zones to evaluate probabilities of exceeding different levels of ground motion at a site.

The earthquake process was assumed to be Poissonian, so foreshocks and aftershocks were not used in determining the magnitude-frequency recurrence relationship.

1. Earthquake Source Zones

These were chosen primarily on the basis of the spatial distribution of magnitude $ML \geqslant 4.0$ earthquakes (Fig. 1). Only events for which epicentres have been reliably determined are shown in this figure. Microearthquakes occur throughout the region and sometimes clusters of events can be related to regional geology (Shirley, 1980), but the larger events occur in two distinct areas: the Western Tasmanian Zone, and the 40°S Zone (West) extending from east of Flinders and Cape Barren Islands into the Tasman Sea (Fig. 1). These, along with the Southern Victorian Zone, the Lachlan Fold Belt Zone, and the 40°S Zone (East) were used as earthquake source zones for the earthquake risk analysis.

(a) Western Tasmanian Zone (Table 1)

As instrumental magnitudes for this zone are available only back to 1958 when the first station of the University of Tasmania seismic net became operational (Carey, 1960), felt reports (Michael-Leiba in prep.) were used to obtain data for numbers of magnitude MI $\geqslant$ 5.0 and 5.5 events back to 1853.

Magnitude MI $\geqslant$ 5.5 events are probably complete for this period for the whole of the Western Tasmanian Zone. However, 5.5 $\geqslant$ MI $\geqslant$ 5.0 events may be complete only for 95 per cent of the source zone prior to 1958 because, if they occurred in the northwestern corner of the Zone, they probably would not have been felt strongly enough in mainland Tasmania to be identified as being of this magnitude. This has been taken into account by taking the number of pre-1958 events to be 3.158 instead of 3. This makes the mean number per year, for the period 1853-1984, 0.0317 instead of 0.0305, which makes a negligible difference in Figure 2 compared with the plus or minus one standard deviation error bars calculated acording to the method of Weichert (1980). Figure 2 gives a return period of about 30 years for a magnitude ML $\geqslant$ 5.0 event, 90 years for a magnitude ML $\geqslant$ 5.5 event, and 290 years for a magnitude ML $\geqslant$ 6.0 earthquake. Because of the uncertainties in the data plotted in Fig. 2, the line was fitted by eye. Its equation is

$$\log N = 3.5 - 1.0\ ML$$

where N is the mean yearly number of earthquakes with Richter magnitudes $\geqslant$ ML. It gives most weight to the magnitude ML $\geqslant$ 4.0 and ML $\geqslant$ 4.5 data as these are based on instrumental data collected over more than 20 years. The data for the smaller events appear to be incomplete (but this is unlikely because, from 1977 on, there was good coverage from Phillip Institute of Technology seismographs in

Victoria, as well as from the Tasmanian seismographs) or are unrepresentative as they are for a period of only 8 years. The data for the larger events are based mainly on felt reports and are less reliable.

The completeness periods used for plotting the points in Fig. 2 were: for ML$\geqslant$ 3.0 and 3.5, 1977-1984; for ML$\geqslant$4.0, 1962-1984; for ML$\geqslant$4.5, 1958-1984; and for ML$\geqslant$5.0, 1853-1984.

We chose a maximum magnitude of ML6.0 for this source zone. The largest earthquake (Fig. 1) occurred on 3 February 1880 and had a magnitude MI 5.6 (Michael-Leiba in prep).

McCue (1978) mentioned the existence of two possible Holocene fault scarps. One of these, the Lake Edgar Fault, although probably an old fracture, appears to have been recently active and the site of large earthquakes according to the field observations of Carey (1960). Microearthquake activity occurs near its northern end (Shirley, 1980). The 3 February 1880 event, while located only approximately, may have occurred on this fault (Michael-Leiba, in prep), so the boundary of the Western Tasmanian Zone was extended to include the Lake Edgar fault.

In conformity with the rest of eastern Australia (Gaull, Michael-Leiba and Rynn, in prep) and because we cannot do any better with hypocentral locations, 10 km was the depth used for earthquake risk calculations.

(b) 40°S Zone (West) (Table 2)

Carey (1960) catalogued 2540 events felt in northeastern Tasmania during the period 1883 to 1886. The activity continued intermittently until 1892. The maximum intensity reported in northeastern Tasmania in 1883 was MMV (Carey, 1960); in 1884-5, MMVI-VIII and in 1892, MMVI-VII (Michael-Leiba, in prep.). Shirley (1980) notes that this swarm of earthquakes appears to have originated in the 40°S Zone (West) but unfortunately, there were no felt reports from Flinders Island. However, recent work (Michael-Leiba, in prep.) suggests that the three largest events (13 July 1884, 12 May 1885 and 26 January 1892) had magnitudes MI 6.4, 6.8 and 7.0 respectively and their epicentres are situated in the 40°S Zone (West).

The events of 1884 and 1885 occurred during a period of almost continuous swarm activity and consequently are not necessarily independent. There were several periods with no felt reports in the years 1888-1891 so we considered the earthquake of 26 January 1892 to be an independent event. Hence, there are at least two independent magnitude MI $\geqslant$ 6.5 events in the 131 years since 1853.

An examination of the felt reports tabulated in Ripper (1963), and of events catalogued in the BMR earthquake data file, suggest that approximately 23 independent events with ML $\geqslant$ 4.0 occurred in the 40°S Zone (West) during the period 1883-1984 (Table 2). Two of these had magnitude MI $\geqslant$ 6.5, as discussed above. We assigned approximate magnitudes, ?MI, (on the basis of maximum reported intensity (Ripper, 1963) at an estimated distance from the epicentres, and of area over which the event was felt (Ripper, 1963), by using the eastern Australian attenuation curves) to those earthquakes whose magnitudes had not been determined instrumentally or from isoseismal maps. We plotted these magnitude-frequency recurrence data in Fig. 3, using 1883-1984 as the completeness period for ML4.0-5.9; and 1853-1984 as the completeness period for events with ML$\geqslant$ 6.0, and the relation determined by eye is

$$\log N = 1.8 - 0.6\ ML$$

The maximum magnitude for the 40°S Zone (West) was taken to be 7.5 because of the magnitude MI6.5 - 7.0 events in the swarm (see Table 2).

Reliable focal depths for the zone are non-existent, so a depth of 10 km was chosen for the earthquake risk calculations.

From Figure 3, the return period for a magnitude ML6.0 event is about 70 years, for a magnitude ML6.5 earthquake, 140 years, and for a magnitude ML7.0 event, 290 years.

(c) Other zones

Because of their proximity to Tasmania, the Southern Victorian and the Lachlan Fold Belt Zones and the 40°S Zone (East) contribute to earthquake risk there and hence have been included in the analysis.

The parameters of the earthquake source zones are given in Table 3. Those for the Southern Victorian and Lachlan Fold Belt Zones were obtained from Gaull, Michael-Leiba and Rynn (in prep.).

The magnitude-frequency recurrence relation,

$$\log N = 3.3 - 0.9\ ML$$

fitted by eye for the 40°S Zone (East), is based on instrumental data from 1903-1984 and shown in Fig. 4. The completeness periods used were 1977-1984 for ML4.0-4.9; 1961-1984 for ML5.0-5.4; and 1903-1984 for ML$\geqslant$5.5.

2. Background Seismicity

The epicentres not included in the source zones are considered to be background seismicity. For the Tasmanian earthquake risk calculations, the mean eastern Australian background seismicity (Gaull, Michael-Leiba and Rynn, in prep.) was used. The parameters are shown in Table 3 where the seismicity rate refers to an area of 10 000 km^2.

3. Strong ground-motion attenuation

As isoseismal maps have been published for only four Tasmanian earthquakes for which instrumental magnitudes are available (Everingham and others, 1982), we used the average eastern Australian attenuation derived in Gaull, Michael-Leiba and Rynn (in prep.) for the earthquake risk assessment. The attenuation constants are given in Table 4.

As three of the isoseismal maps had irregular isoseismals and no individual felt intensities marked on the maps, and the fourth (Queenstown, 1 January 1958) was based on felt reports from only 11 places, it is difficult to assess how the Tasmanian attenuation compares with that used in this study, except to say that it is not grossly inconsistent.

RESULTS

Earthquake risk for the Tasmanian region was computed and plotted on a 0.25° grid near the source zones and a 0.5° grid elsewhere. The contours of peak ground velocity, peak ground acceleration, and Modified Mercalli intensity with a 10 per cent probability of being exceeded in a 50 year period are shown in Fig. 5, 6 and 7. Because the effect of water on strong motion on the sea floor is unknown the offshore contours are dotted.

The land areas subject to the highest risk are Flinders and Cape Barren Islands which lie adjacent to the 40°S Zone (West) and are predominantly between the $60mm.s^{-1}/0.6m.s^{-2}$ and $120mm.s^{-1}/1.2m.s^{-2}$ contours in Fig. 5.

The second highest risk land area is that part of western and northwestern Tasmania within the $59\ mm.s^{-1}/0.55ms^{-2}$ contour in Figures 5 and 6. It is estimated that at Queenstown there is a 10 per cent chance that the ground motion will exceed $58\ mm.s^{-1}$ or $0.54\ m.s^{-2}$ during a 50 year period. According to our scaling rule this corresponds to an intensity of MMVI-VII, which is the threshold at which damage can occur.

At Devonport, just outside the Western Tasmanian source zone, there is a 10 per cent probability that ground motion will exceed $33\ mm.s^{-1}$ or $0.31\ m.s^{-2}$ (intensity MMV-VI) during a 50 year period. At Hobart, the corresponding figures are $23\ mm.s^{-1}$ or
$0.21\ m.s^{-2}$ (intensity MMIV-V); and at Launceston $30\ mm.s^{-1}$ or
$0.29\ m.s.^{-2}$ (intensity MMIV-V), well below the damage threshold.

DISCUSSION

The earthquake risk calculations indicate that the 100 year intensities at Queenstown and Flinders Island should be MMV-VI, while at Devonport, Launceston, and Hobart they should be MMIV-V. These results are reasonably consistent with the macroseismic data available for the period 1885 to 1984. Queenstown recorded intensity MMIV-VII in 1908 (Michael-Leiba, in prep.), MMIV-VI in 1911 (Michael-Leiba, in prep.), and intensity MMV in 1958, (Everingham and others, 1982). MMIV was experienced at Devonport in 1909 (Ripper 1963), and MMII-VI in 1924 (Michael-Leiba, in prep.). Hobart recorded intensities of MMIV-VI in 1885 and 1892 (Michael-Leiba in prep), and MMIV in 1922 (Ripper 1963). Intensity MMIV has been observed at Flinders Island in 1948 and 1954 (Ripper 1963) but the felt reports from Flinders Island are obviously incomplete.

However, Launceston experienced intensity MMIV in 1900, 1948 and twice in 1887 (Ripper 1963), MMV in 1946 (Ripper, 1963), MMIV-VII in 1885 and MMV-VII in 1892 (Michael-Leiba in prep). For seven out of eight earthquakes for which isoseismal maps were drawn, and which were felt in Launceston during the period 1859-1964 (Everingham and others, 1982; Michael-Leiba, in prep.), the maximum intensity experienced there was greater than that expected for an average site by one to two intensity units. For six out of eight events, even the mean intensity at Launceston was about one intensity unit greater than that for an "average site". Consequently the ground motion in some parts of Launceston appears to be underestimated by the risk maps.

This is because the risk calculations assume average site conditions and there appears to be a local site effect in parts of Launceston, particularly the area (including the central business district) immediately south and southeast of the junction of the Tamar and North Esk Rivers. Minor damage occurred in this area during the 1883-1892 earthquake swarm, (Michael-Leiba, in prep.). Also a magnitude ML 5.7 event on 14 September 1946, 200 km away, was felt in Launceston with intensity MMV (Ripper, 1963). This is because Launceston is built on a complex northnorthwest-trending Tertiary graben (in Jurassic dolerite) in which Tertiary lake sediments have been deposted. The area in which the maximum intensities were experienced during the swarm is underlain by up to 200m of Tertiary clays. Because of the complex nature of the graben, their thickness varies from an estimated 200m to zero where dolerite crops out in City Park at the eastern extremity of the area (P. Stephenson, Tasmanian Mines Department, personal communication). The estimated effect of this amplification in the lake sediments of the city is to increase the contours from about $30 mm.s^{-1}$ and $0.29 m.s^{-2}$ to about $60 mm.s^{-1}$ and $0.60 m.s^{-2}$. This should be taken into consideration in seismic zoning in those parts of Launceston underlain by the Tertiary lake sediments.

The earthquake risk map produced by Underwood (1973) bears very little resemblance to our maps because it was based on only 10.5 years of data. However, the earthquake risk assessed by us for the Tasmanian region is very similar to that of McCue (1978), but his western Tasmanian seismic region extends 50-100km further east, and our northeastern Tasmanian risk area extends about 50km south of his.

An uncertain parameter in the Western Tasmanian Zone is the maximum magnitude. The largest event in this region in historic times was a magnitude Ml5.6 earthquake, and we used magnitude ML6.0 for our risk assessment. McCue (1978) deduced an upper bound of magnitude ML6.5 for the Type III extreme value distribution for southeastern Australia. If this were taken to be the maximum magnitude for western Tasmania, then the risk at Queenstown, Devonport and Hobart would be increased slightly. The contour values for Queenstown would change from 58 $mm.s^{-1}$/0.54 $m.s^{-2}$ to 63 $mm.s^{-1}$/0.59 $m.s^{-2}$. For Devonport, the contour values would change from 33 $mm.s^{-1}$/0.31 $m.s^{-2}$ to 35 $mm.s^{-1}$/0.33 $m.s^{-2}$. At Hobart, they would change from 23 $mm.s^{-1}$/0.21 $m.s^{-2}$ to 25 $mm.s^{-1}$/0.23 $m.s^{-2}$.

Another uncertainty is the attenuation of strong ground motion. We have used an average eastern Australian attenuation (Gaull, Michael-Leiba and Rynn, in prep.). Strong motion data need to be collected for the Tasmanian region to define the attenuation in this area. In southwest Western Australia, the standard deviation of the residuals about the mean isoseismal radii was 0.24 intensity units for the Meeberrie, Meckering and Cadoux earthquakes (Gaull and Michael-Leiba, 1987). We found that taking this into account could cause the probability of a particular event to vary by about 20 percent, so the uncertainty in attenuation in the Tasmanian region would be expected to have at least this effect on the risk figures.

A third uncertainty in the estimation of Tasmanian earthquake risk is caused by lack of instrumental information on the locations and magnitudes of earthquakes which occurred prior to the establishment of the Tasmanian seismic net. The first station was not opened until 1957 (Carey, 1960). There were few or no instruments to locate events accurately before this, or to determine their magnitudes. Some errors and omissions in existing catalogues have been corrected for this study (Table 1 and 2, and Michael-Leiba, in prep), but more research into the magnitudes and epicentres of early earthquakes, particularly those asterisked in Table 2 needs to be done.

CONCLUSIONS

The earthquake risk maps presented here depict contours of peak ground velocity, acceleration and intensity with a 10 per cent probability of being exceeded in a 50 year period. Because of the unknown effect of water on strong motion on the ocean floor the offshore contours have been dotted.

The highest risk land areas are Flinders and Cape Barren Islands (which lie predominantly between the $60mm.s^{-1}/0.6m.s^{-2}$ and $120mm.s^{-1}/1.2m.s^{-2}$ contours) followed by the northern part of western Tasmania ($59\ mm.s^{-1}/0.55\ m.s^{-2}$).

The chief contributors to uncertainty in the estimation of earthquake risk are uncertainties in early earthquake locations and magnitudes, and in strong ground motion attenuation.

We recommend that special attention be given to the microzoning of Launceston because of site effects.

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REFERENCES

Basham, P.W., Weichert, D.H., Anglin, F.M., and Berry, M.J., 1985. New probabilistic strong ground motion maps of Canada. Bulletin of the Seismological Society of America, v. 75, no. 2, pp. 563-595.

Carey, S.W., 1960. Tasmania University Seismic Net. Publication 84, Geology Department, University of Tasmania.

Denham, D., 1976. Earthquake hazard in Australia. Australian Academy of Science, v. 7, pp. 94-118.

Cornell, C.A., 1968. Engineering seismic risk analysis. Bulletin of the Seismological Society of America, V.58, no. 5.

Everingham, I.B., McEwin, A.J., and Denham, D., 1982. Atlas of isoseismal maps of Australian earthquakes. Bureau of Mineral Resources, Australia, Bulletin 214.

Gaull, B.A., Michael-Leiba, M.O., and Rynn, J.M.W., in prep. Probabilistic earthquake risk maps of Australia.

Kanai, K., 1961. An empirical formula for the spectrum of strong earthquake motions. Bulletin of the Earthquake Research Institute, University of Tokyo, 39(1), 85-96.

McCue, K.F., 1978. Seismic risk in Eastern Australia. University of Adelaide, Physics Department, Publication ADP 153.

Michael-Leiba, M.O. (in prep.). Macroseismic effects, locations and magnitudes of some early Tasmanian earthquakes.

Ripper, I.D., 1963. Local and regional events recorded by the Tasmania seismic net. Univ. of Tasmania Honours Thesis (Unpubl.).

McEwin, A., Underwood, R., and Denham, D., 1975. Earthquake risk in Australia. BMR Journal of Australian Geology and Geophysics, V.1, pp. 15-21.

McGuire, R.K., 1976. Fortran computer program for seismic risk analysis. USGS Open File Report 76-67.

Shirley, J.E., 1980. Tasmanian seismicity - natural and reservoir induced. Bulletin of the Seismological Society of America, v. 70, no. 6, pp. 2203-2220.

Underwood, R., 1973. Progress report on seismic zoning in Australia Bureau of Mineral Resources, Australia, Bulletin 164, pp. 61-66.

Weichert, D.H., 1980. Estimation of the earthquake recurrence parameters for unequal observation periods for different magnitudes. Bulletin of the Seismological Society of America, v. 70, no. 4, pp. 1337-1346.

Table 1: Main shocks in the Western Tasmanian Zone (1853-1984). Foreshocks and aftershocks are not included

Date	Latitude	Longitude	Depth	Magnitude	Comments
y m d	°S	°E	km		
1859 11 21	40.7°S	145.2°E	-	~~5.3~~ 5.4 MI	Isoseismal map drawn (Michael-Leiba in prep)
1880 02 03	43.0°S	146.3°E	-	~~5.6~~ 5.5 MI	Isoseismal map drawn (Michael-Leiba in prep)
1908 05 04	42.0°S	145.4°E	-	4.8 MI	Isoseismal map drawn (Michael-Leiba in prep)
1911 11 04	42.2°S	145.2°E	-	4.8 MI	Isoseismal map drawn (Michael-Leiba in prep)
1924 03 01	41.7°S	145.0°E	-	5.2 MI	Isoseismal map drawn (Michael-Leiba in prep)
1958 01 01	42.2°S	146.1°E	10G	5.3 ML(RIV)	BMR EDF
1962 06 01	42.85°S	145.51°E	10G	3.2 ML(TAU)	BMR EDF
1963 11 03	43.49°S	145.80°E	10G	4.4 ML(BMR)	BMR EDF
1964 11 14	40.22°S	144.60°E	10G	4.5 ML(TAU)	BMR EDF
1964 12 09	41.80°S	146.62°E	10G	3.4 ML(TAU)	BMR EDF
1966 07 05	39.65°S	144.96°E	62	4.1 ML(CAN)	BMR EDF
1967 11 30	42.76°S	146.45°E	10G	3.5 ML(TAU)	BMR EDF
1969 03 13	41.32°S	144.75°E	10G	3.5 ML(TAU)	BMR EDF
1971 05 26	40.48°S	145.01°E	10G	3.0 ML(TAU)	BMR EDF
1971 06 15	40.98°S	145.83°E	10G	4.0 ML(TAU)	BMR EDF
1971 10 22	40.90°S	143.93°E	10G	3.2 ML(TAU)	BMR EDF
1972 03 04	41.93°S	145.41°E	10G	3.0 ML(TAU)	BMR EDF
1973 06 03	42.32°S	145.08°E	10G	4.0 ML(BMR)	BMR EDF
1975 05 03	41.62°S	143.98°E	-	4.5 ML(TAU)	BMR EDF
1975 08 31	39.95°S	144.77°E	-	3.5 ML(TAU)	BMR EDF
1977 12 21	42.98°S	146.08°E	-	3.0 ML(TAU)	BMR EDF
1978 05 04	41.02°S	145.68°E	12	3.0 ML(BMR)	BMR EDF
1978 08 25	42.98°S	145.78°E	20	3.0 ML(TAU)	BMR EDF
1979 07 11	39.97°S	144.61°E	11	3.9 MD(PIT)	BMR EDF
1979 07 28	40.52°S	144.72°E	-	3.0 ML(TAU)	BMR EDF
1979 09 10	39.72°S	144.65°E	15	3.6 MD(PIT)	BMR EDF
1981 12 08	39.67°S	144.38°E	-	3.0 ML(TAU)	BMR EDF
1982 04 01	40.26°S	142.93°E	-	4.0 ML(TAU)	BMR EDF
1982 08 19	40.61°S	145.19°E	0	3.6 ML(BMR)	BMR EDF
1982 12 10	40.15°S	143.87°E	-	3.0 ML(TAU)	BMR EDF
1983 10 15	39.78°S	145.03°E	10	4.4 ML(PIT)	BMR EDF

ML Instrumentally determined Richter magnitude.
MI Magnitude (Richter equivalent) determined from isoseismal radii on an isoseismal map.

BMR	Bureau of Mineral Resources
CAN	Australian National University
PIT	Phillip Institute of Technology
RIV	Riverview Observatory
TAU	University of Tasmania
BMR EDF	BMR Earthquake Data File

Table 2: Main shocks in the 40°S Zone (West)(1853-1984) Foreshocks and aftershocks and swarm events within 1 month of one another are not included.

Date y m d	Latitude °S	Longitude °E	Depth km	Magnitude	Comments
1885 05 12	39.8	148.8	-	6.8 MI	Michael-Leiba(in prep)
1888 05 28	-	-	-	?5.0-5.5 MI	*Felt E.Tas
1889 12 07	-	-	-	?4.0-4.5 MI	*Felt IIIGoulds Country
1890 04 29	-	-	-	?4.0-4.5 MI	*Felt IIIGoulds Country
1890 08 11	-	-	-	?4.0-4.5 MI	*Felt IIIGoulds Country
1891 05 30	-	-	-	?4.5-5.0 MI	*Felt IV St. Marys
1891 07 02	-	-	-	?4.0-4.5 MI	*Felt III St. Helens
1892 01 26	40.3	149.5	-	6.9 MI	Michael-Leiba(in prep)
1894 01 26	-	-	-	?4.0-4.5 MI	*Felt IIIGoulds Country
1894 11 22	-	-	-	?5.0-5.5 MI	*Felt Eastern Tasmania
1895 12 02	-	-	-	?4.0-4.5 MI	*FeltIIIGoulds Country
1897 05 25	-	-	-	?4.0-4.5 MI	*FeltIV Eddystone
1897 08 11	-	-	-	?4.5-5.0 MI	*Felt NE. Tas.
1903 12 31	-	-	-	?4.5-5.0 MI	*Felt IV St. Helens
1907 01 31	-	-	-	?5.0-5.5 MI	*Felt E. Tas.
1928 01 18	-	-	-	?4.0-4.5 MI	*Felt III Scottsdale
1929 12 28	39.69	149.45	10G	5.4 ML(RIV)	BMR EDF
1946 09 14	40.20	149.00	33G	5.7 ML(RIV)	BMR EDF
1948 08 10	-	-	-	?4.0-4.5 MI	*Felt IV Flinders Is.
1954 12 11	-	-	-	?4.0-4.5 MI	*Felt IV Flinders Is.
1961 02 03	40.0	148.5	0G	4.0 ML(CAN)	BMR EDF
1965 03 18	40.29	149.59	33G	5.0 ML(CAN)	BMR EDF
1972 05 14	40.10	150.33	0G	4.3 ML(CAN)	D.Denham-pers. comm

* Felt report from Ripper, 1963
?MI Rough estimate of Richter magnitude from scanty intensity data - no isoseismal map drawn
Other symbols and abbreviations are the same as in Table 1

Another big one was:
Cape Barren I. 0355UT 13/7/1884
40·5°S, 148·5°E magnitude 6·4 MI

Table 3. Earthquake source zone parameters

Source Zone	ML(Min)	ML(Max)	b	A(Min)
Western Tasmania	3.0	6.0	1.00	3.50
40°S (West)	4.0	7.5	0.63	0.30
40°S (East)	4.0	7.0	0.88	0.59
Southern Victoria	3.0	6.0	0.77	2.26
Lachlan Fold Belt	3.0	6.1	1.16	14.69
Background	2.0	5.5	0.83	0.14

ML(Min) = Minimum Richter magnitude

ML(Max) = Adopted Maximum Richter magnitude

A(Min) = Number of earthquakes per annum above ML(Min)

b = b-value (slope) of magnitude-frequency relationship.

Table 4 Attenuation constants adopted for Tasmanian earthquake risk map

Using the Kanai (1961) form:

$Y = ae^{bML}R^{-c}$, where Y is the peak ground motion

ML is Richter magnitude

and R is hypocentral distance in kilometres

Peak Ground Motion (Y)	a	b	c
Intensity (MM) = ln Y	50	1.50	1.7
Velocity ($mm.s^{-1}$)	12.20	1.04	1.18
Acceleration ($m.s^{-2}$)	0.088	1.10	1.20

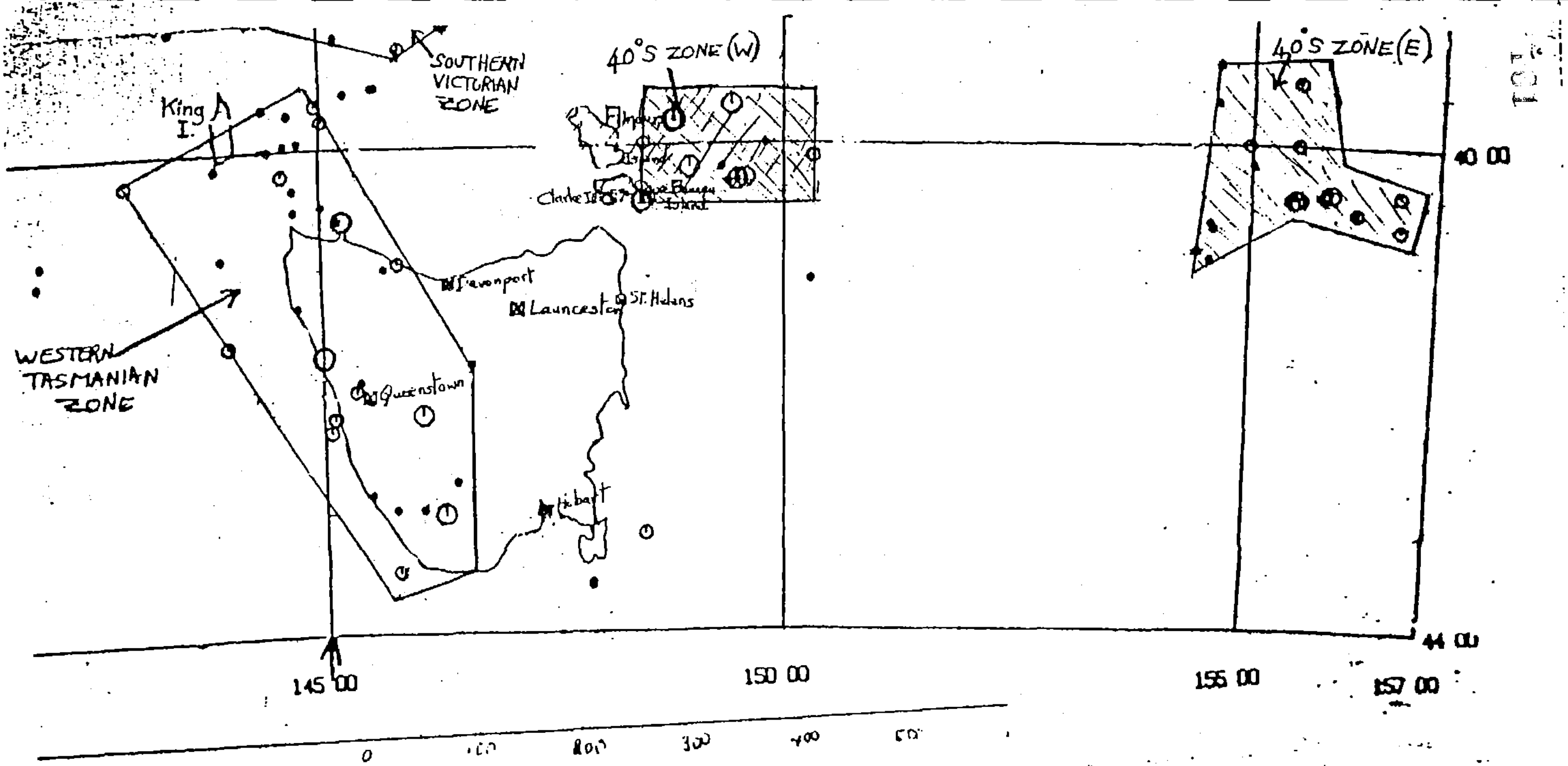


FIGURE 1: EARTHQUAKE SOURCE ZONES AND EPICENTRES IN THE TASMANIAN REGION.

MAGNITUDE

<4.00 4.00-4.99 >4.99

775162

775163

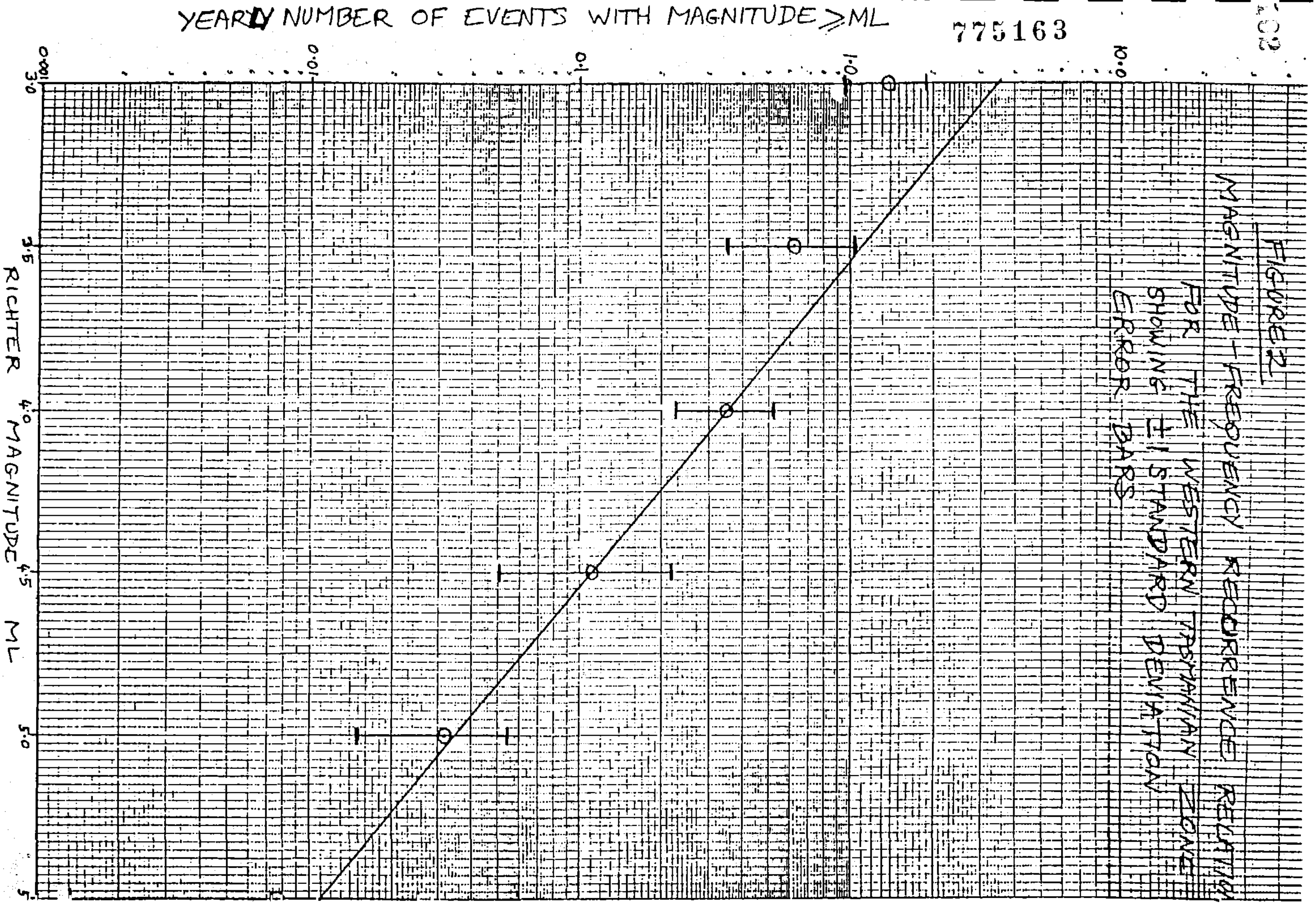
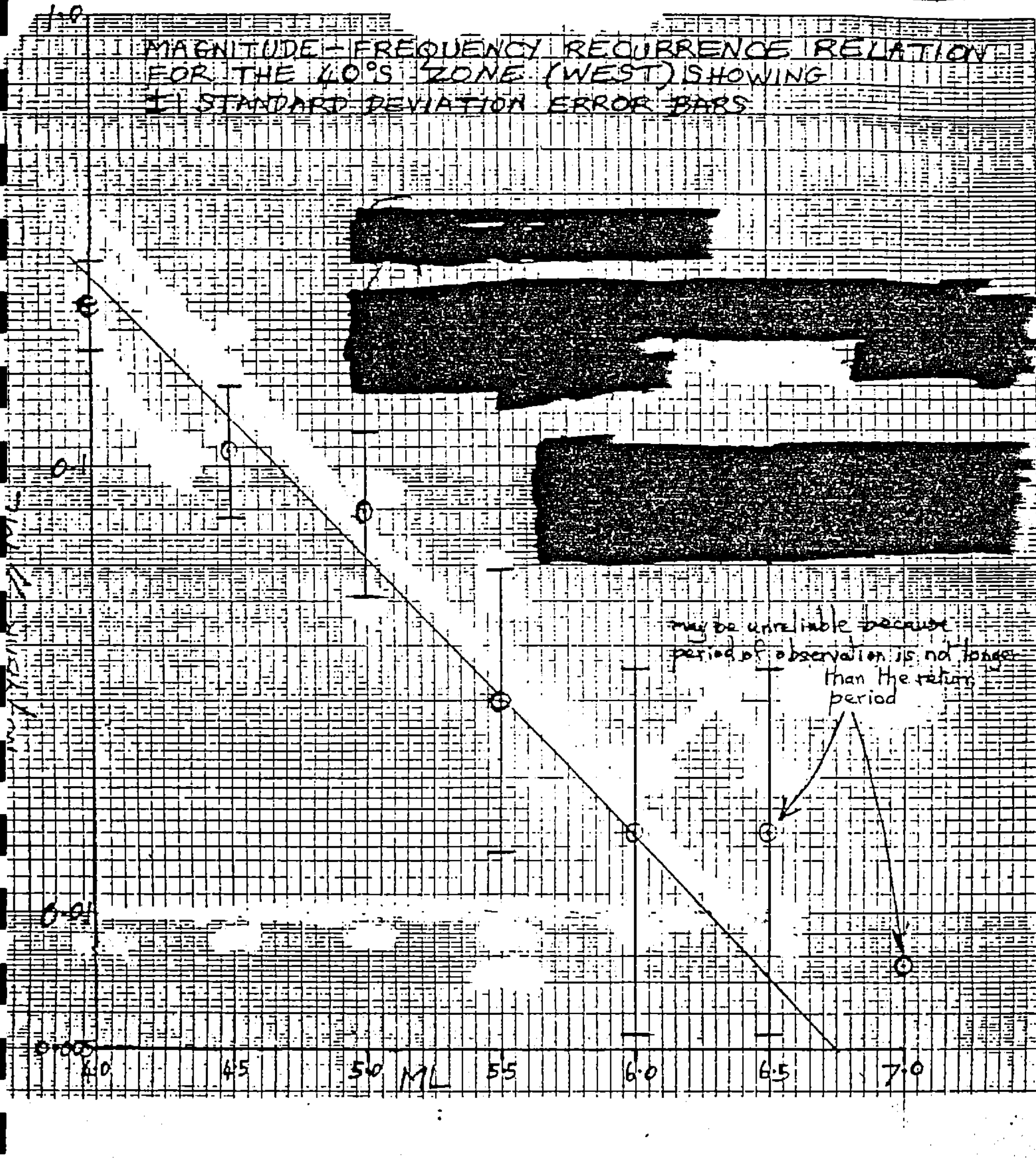


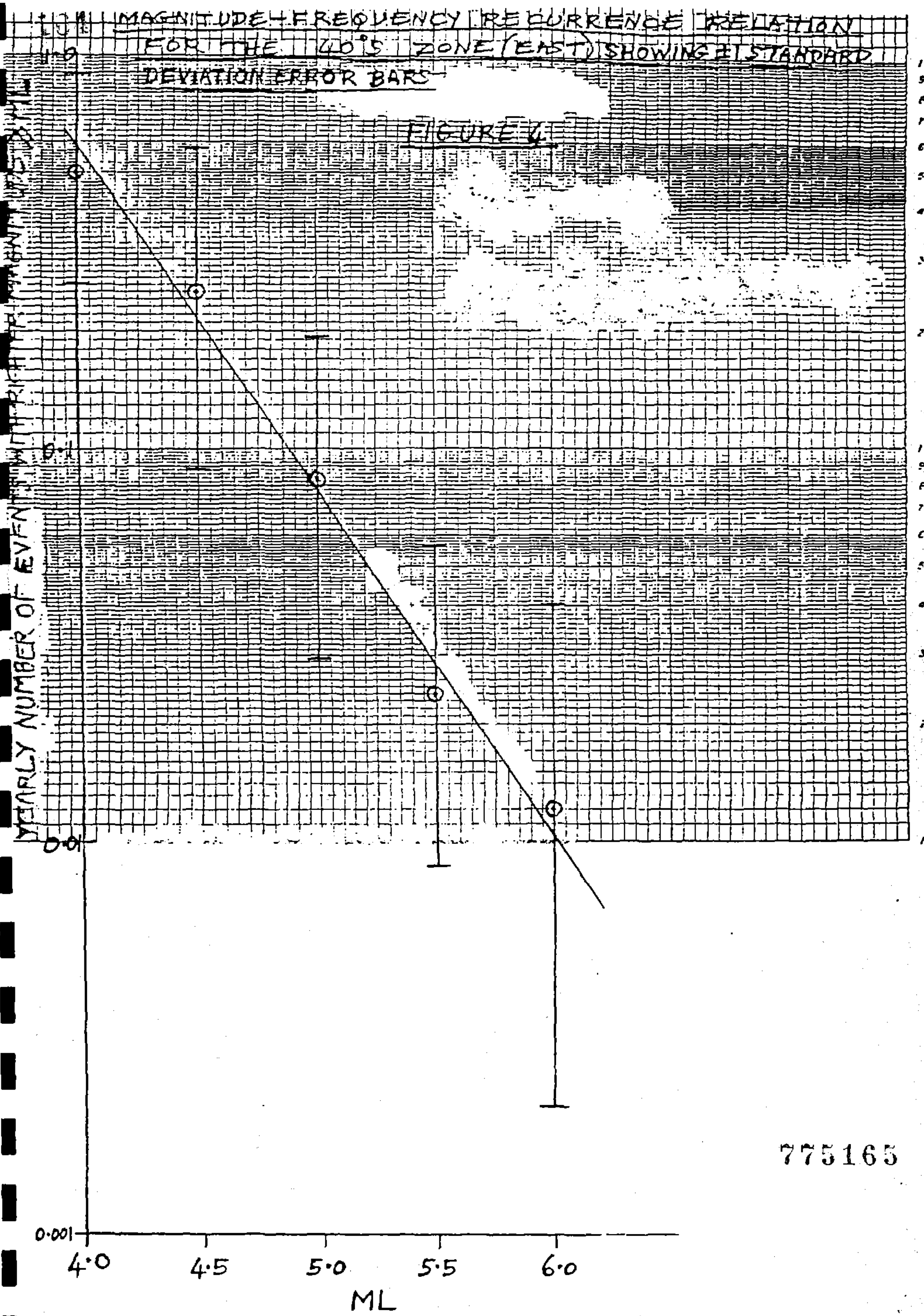
FIGURE 2
MAGNITUDE-FREQUENCY RECURRENCE RELATION FOR THE WESTERN TRANSVAAL ZONE SHOWING ±1 STANDARD DEVIATION ERROR BARS

775164

FIGURE 3

(12/5/87)




MAGNITUDE-FREQUENCY RECURRENCE RELATION
FOR THE 40°S ZONE (EAST) SHOWING ±1 STANDARD
DEVIATION ERROR BARS
FIGURE 4
YEARLY NUMBER OF EVEN
1.0
0.1
0.01
0.001
4·0
4·5
5·0
5·5
6·0
ML

775165

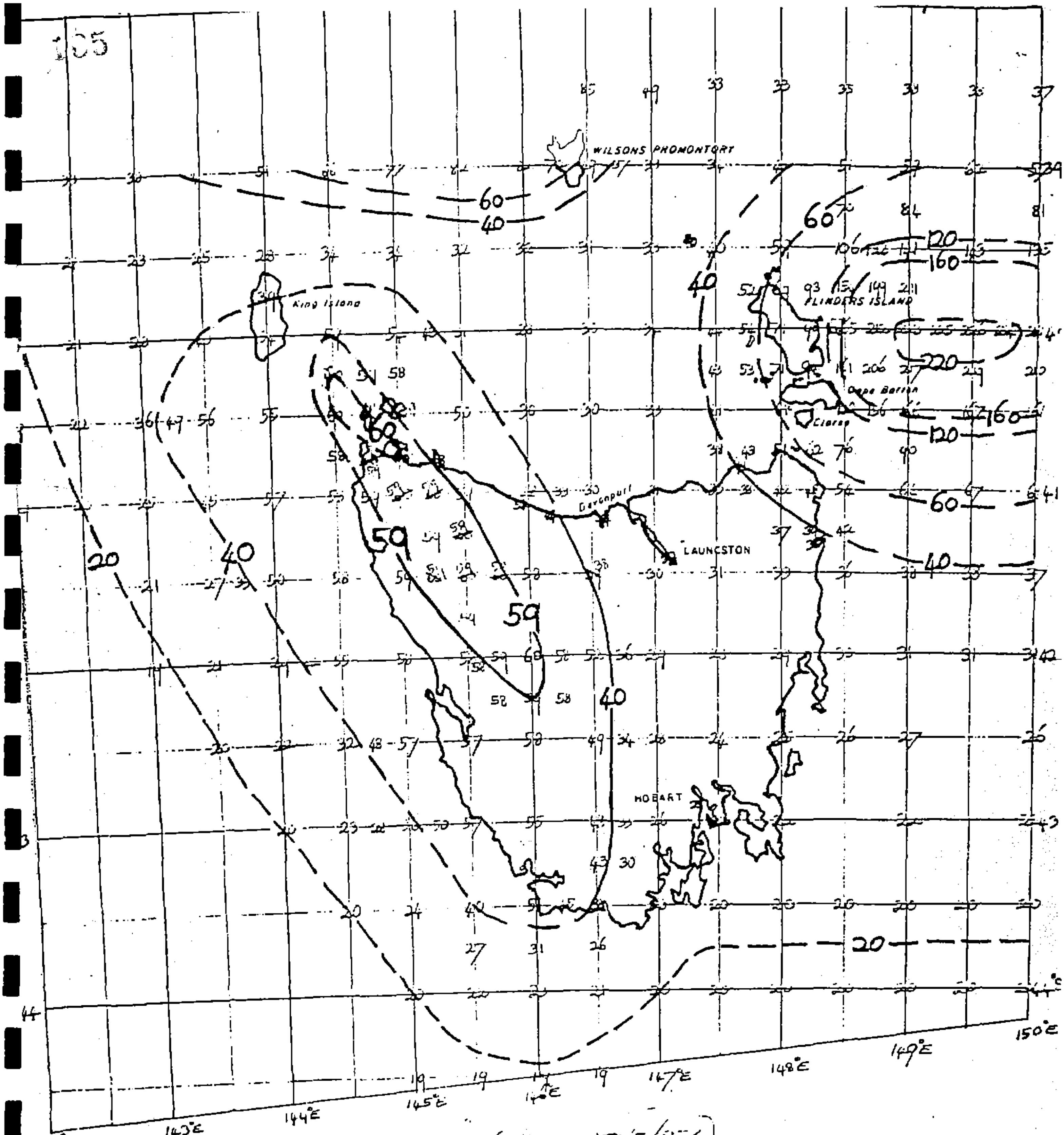
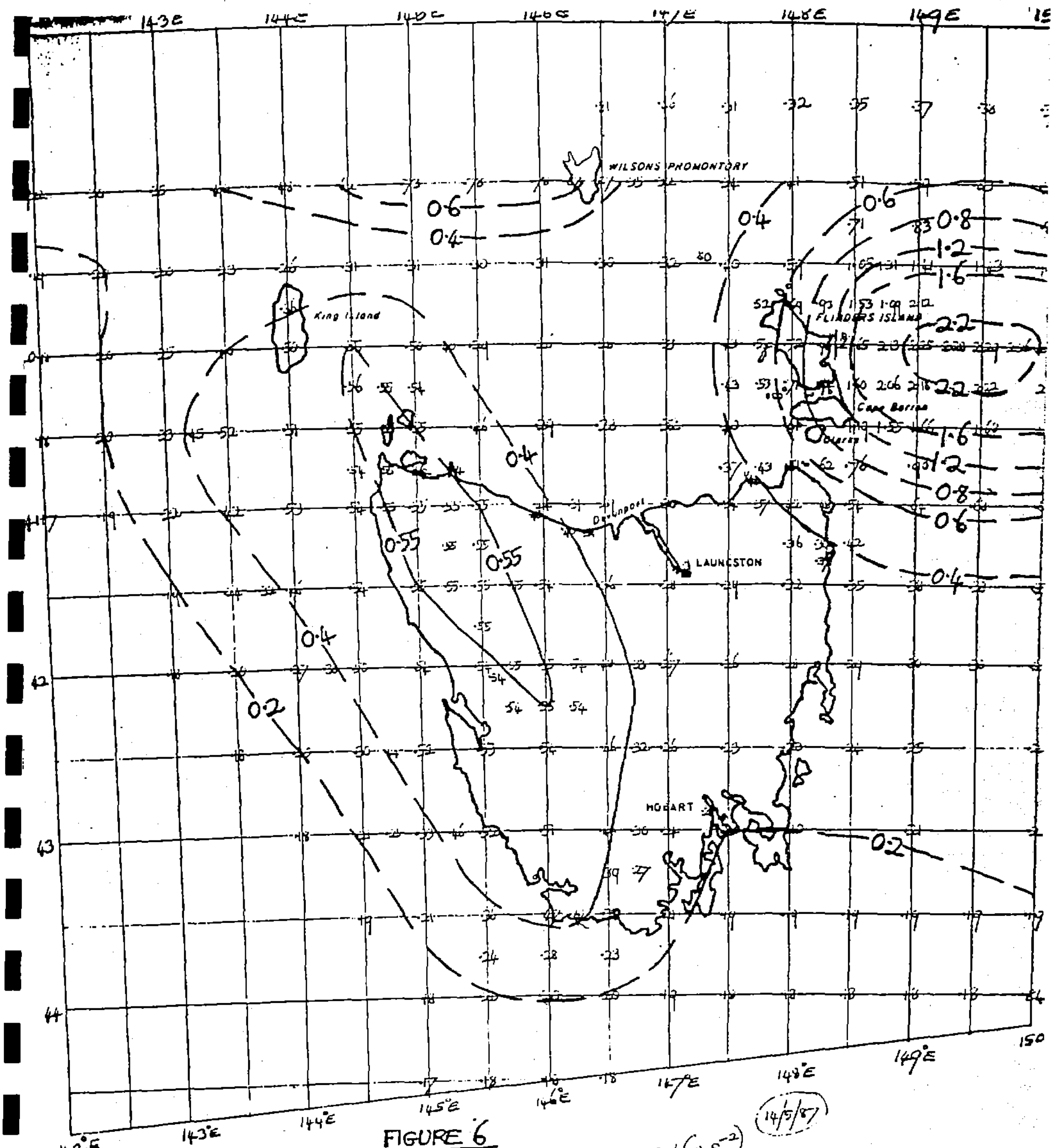


FIGURE 5 PEAK GROUND VELOCITY (mm/s) WITH A 10% CHANCE OF BEING EXCEEDED IN A 50 YEAR PERIOD

12/5/87

775166



(14/5/87)

FIGURE 6

PEAK GROUND ACCELERATION ($m.s^{-2}$) WITH A 10% CHANCE OF BEING EXCEEDED IN A 50 YEAR PERIOD

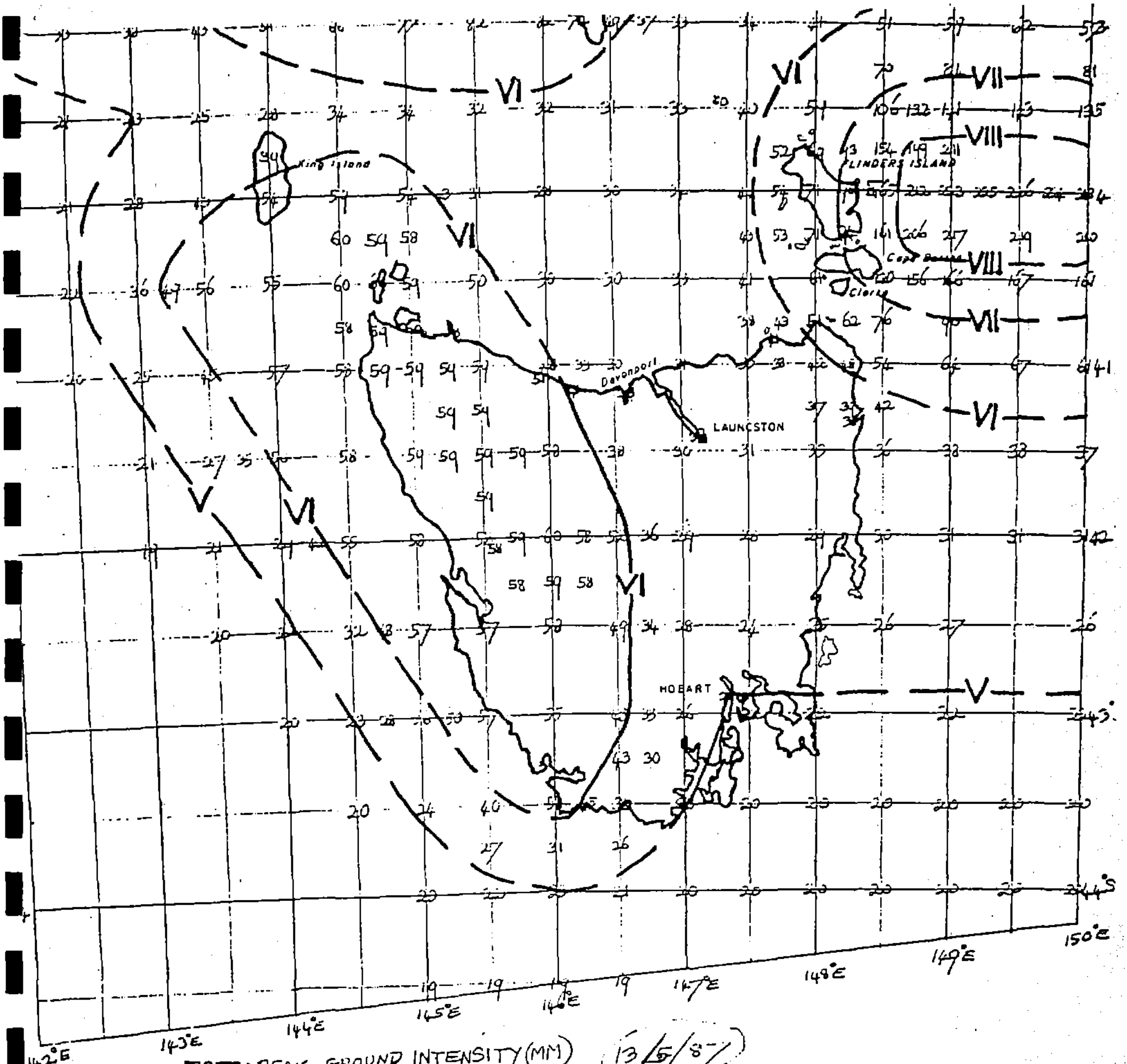


FIG.7: PEAK GROUND INTENSITY (MM) WITH A 10% CHANCE OF BEING EXCEEDED IN A 50 YEAR PERIOD (13/5/87)

From I.D. Ripper (1963) Honours Thesis
Uni. of Tasmania (unpubl.)

Date	Time (GMT)	Region Felt	Maximum Intensity (MM)	Place of Maximum Intensity	No. of Places Felt
1890					
April 29	0450	Goulds Country	III	Goulds Country	4
May 3	1153	Goulds Country	III	Goulds Country	1
Aug. 11	0520	Goulds Country	III	Goulds Country	1
1891					
Jan. 22	1130	Swan Island	III	Swan Island	1
May 30	1505	St. Marys	IV	St. Marys	2
June 26	0635	Swansea	II	Swansea	1
July 2	1025	St. Helens	III	St. Helens	1
4	0530	St. Helens	III	St. Helens	1
1892					
Jan. 24	0945	Flinders Island *	II	Flinders Island	1
26	1635	Tas, Vic, N.S.W.	VI	Launceston	all Tas.
26	1645	Tas, Vic, N.S.W.	III	Launceston	all Tas.
Feb. 11	1750	Launceston	III	Launceston	1
March 21	1535	Launceston	III	Launceston	1
Aug. 30	1100	Goose Island	II	Goose Island	1
26. 1.1894	0250	Goulds Country	III	Goulds Country	1
28. 5.1894	0830	Stanley *	III	Stanley	2
22.11.1894	0215	Eastern Tasmania	IV	Goulds Country	11
22.11.1894	0233	Eastern Tasmania	IV	Goulds Country	6
1.11.1895	2030	Launceston	III	Launceston	2
2.12.1895	2100	Goulds Country	III	Goulds Country	1
6. 4.1897	1145	Pyramid Hill	IV	Pyramid Hill	2
25. 5.1897	0730	Eddystone	IV	Eddystone	1
25. 5.1897	1503	Hobart	II	Hobart	1
9. 8.1897	1130	Devonport	III	Devonport	1
9. 8.1897	1400	Devonport	III	Devonport	1
11. 8.1897	1000	N.E. Tasmania	IV	Fingal	6
18. 6.1899	2100	Stanley	IV	Stanley	2
1. 9. 1899	2048	Launceston	III	Launceston	3
20. 6.1902	1900	Launcestion	IV	Launceston	1
27. 7. 1902	1400	Latrobe	IV	Latrobe	1
25. 5.1903	2000	Ulverstone	III	Ulverstone	1
31.12.1903	1100	St. Helens	IV	St. Helens	1
25. 3.1905	1248	North Tasmania	III	Devonport	6
14. 8.1906	0910	Goose Island	III	Goose Island	1
31. 1.1907	0730	Eastern Tasmania *	IV	Ringarooma	19

20. 5.1907	unknown	Stanley	V	Stanley	2	[illegible]
8. 9.1907	0830	Ulverstone	IV	Preston	4	
4. 5.1908	0938	North West Tas.*	IV	Queenstown	10	ML(I)=4
19. 1.1909	1400	Devonport	IV	Devonport	1	
22. 6.1910	0810	Eddystone	III	Eddystone	2	
24. 7.1910	1300	Launceston	III	Launceston	1	
7. 8.1910	1425	Hobart	III	Hobart	3	
27. 2.1911	1000	Stanley	IV	Stanley	1	
4.11.1911	0127	West Tasmania*	V	Zeehan	5	ML(I)=4
13. 3.1915	unknown	Levendale	II	Levendale	1	
21.12.1917	1700	Smithton	III	Smithton	3	
31. 7.1919	1425	Cressy	III	Cressy	1	
10. 4.1922	1100	Stanley*	III	Stanley	2	
27. 4.1922	1900	Hobart	IV	Hobart	1	
7. 5.1922	unknown	Southport	IV	Southport	1	
1. 3.1924	1200	N.W. & West Tas.	III	Queenstown	5	ML(I)=5
25. 4.1925	1300	N.W. Coast Tas.	III	unknown	1	
18. 1.1928	0124	Scottsdale	III	Scottsdale	2	
12. 5.1928	0500	Smithton	IV	Smithton	1	
30. 5.1928	unknown	Montague	IV	Montague	1	
28.12.1929	0130	Legerwood*	VI	Legerwood	2	
4. 1.1930	unknown	Oatlands	IV	Oatlands	1	
21. 4.1930	1900	Stanley	IV	Stanley	1	
13. 3.1931	2100	Burnie	IV	Burnie	2	
14. 2.1932	1600	Gladstone	III	Gladstone	1	
13.10.1932	1630	Montagu	IV	Montagu	2	
30. 9.1933	1045	Scottsdale	II	Scottsdale	1	
4. 9.1937	1315	Scottsdale	II	Scottsdale	1	
13.12.1938	1345	Stanley	III	Stanley	1	
6. 9.1942	1630	Stanley	IV	Stanley	1	
29. 1.1946	1330	Stanley	III	Stanley	1	

14. 9.1946	2000	Tasmania	V	Launceston	8 ML = 5.7
21. 5.1947	1030	Smithton	III	Smithton	1
10. 8.1948	1455	Flinders Island	IV	Flinders Island	1
11. 9.1948	0400	Launceston	IV	Launceston	3
24.10.1953	0315	Somerset	IV	Somerset	1
11.12.1954	1330	Flinders Island	IV	Flinders Island	1
~~26. 4.1955~~	~~1[illegible]~~	~~North West Tas.~~	~~IV~~	~~Forest~~ This was a big storm, not an earthquake	
1. 1.1958	0007	Southern Tasmania	IV	Queenstown	10
25. 5.1958	unknown	Kettering	III	Kettering	1
20. 6.1958	2335	Hobart	II	Hobart	1
21. 8.1962	2052	Cygnet area*	III	Cygnet	6

775172

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
ISS	1922- 7-13	0122 46.0	148.500	-43.200	33.0	4.0		ML 4.0 PMM
DES	1958- 1- 1	0007 0.0	146.100	-42.200	10.0 6	5.3		ML 5.3 RIV
TASU	1960-11- 2	1941 22.0	148.360	-43.610	10.0 R			
TASU	1961- 3-14	0454 1.0	145.040	-41.030	10.0 R			
TASU	1961- 4-26	1708 37.0	145.450	-41.570	10.0 R			
TASU	1961- 5- 9	0852 8.0	145.500	-43.000	10.0 R			
TASU	1961- 7-19	0530 50.2	145.960	-43.470	10.0 R			
TASU	1961-10-24	1959 52.0	145.690	-42.830	10.0 R			
TASU	1961-11- 1	2157 20.0	146.770	-43.280	10.0 R			
TASU	1961-11-11	1024 36.0	145.670	-42.640	10.0 R			
TASU	1961-11-15	0550 22.0	146.060	-42.180	10.0 R			
TASU	1962- 1-29	1100 5.0	145.460	-42.950	10.0 R			
TASU	1962- 4-12	1520 46.0	145.120	-41.400	10.0 R			
TASU	1962- 6- 1	0419 2.5	145.510	-42.850	10.0 R	3.2		ML 3.2 TAU
TASU	1962- 6- 7	1650 2.5	146.660	-42.750	10.0 R	1.1		ML 1.1 TAU
TASU	1962- 6-27	1007 31.0	146.630	-43.320	10.0 R	1.6		ML 1.6 TAU
TASU	1962- 8-21	2032 48.2	147.061	-43.153	10.0 R	2.5		ML 2.5 TAU
TASU	1962- 8-22	0220 32.0	145.760	-41.870	10.0 R	1.5		ML 1.5 TAU
TASU	1962- 8-22	0549 14.0	145.870	-41.780	10.0 R	1.3		ML 1.3 TAU
TASU	1962- 9- 3	0555 45.0	145.210	-42.760	10.0 R			
TASU	1962- 9- 9	0415 3.0	145.810	-41.990	10.0 R	1.2		ML 1.2 TAU
TASU	1962-10-18	0958 59.5	147.910	-43.620	10.0 R	1.6		ML 1.6 TAU
TASU	1962-12-26	1904 53.0	145.750	-40.940	10.0 R	2.5		ML 2.5 TAU
TASU	1963- 1- 8	2146 14.0	144.590	-41.250	10.0 R	2.7		ML 2.7 TAU
TASU	1963-11- 3	1200 41.0	145.800	-43.490	10.0	4.4	MS 3.9	ML 4.4 BMR
ISC	1964-11-16	0214 0.0	145.500	-42.500	0.0			
TASU	1964-11-18	0205 10.0	145.330	-42.240	10.0 R			
TASU	1964-12- 9	1638 41.0	146.625	-41.803	10.0 R	3.4		ML 3.4 TAU
TASU	1964-12- 9	1648 45.4	146.600	-41.890	10.0 R	2.0		ML 2.0 TAU
TASU	1964-12- 9	1838 16.3	146.730	-41.970	10.0 R	1.4		ML 1.4 TAU
TASU	1965- 4-30	0549 58.0	146.690	-41.870	10.0 R	1.6		ML 1.6 TAU
TASU	1965-11-25	0241 50.0	145.181	-42.169	10.0 R	2.8		ML 2.8 TAU
TASU	1966- 1- 7	1417 15.0	146.432	-42.988	10.0 R	1.6		ML 1.6 TAU
TASU	1966-11-17	0725 41.0	144.936	-41.333	10.0 R	2.2		ML 2.2 TAU
TASU	1967- 1-27	2316 52.0	147.914	-43.596	30.0 R	3.0		ML 3.0 TAU
TASU	1967-10- 6	0559 9.0	147.910	-43.630	10.0 R	3.1		ML 3.1 TAU
TASU	1967-11-30	0544 45.0	146.450	-42.756	10.0 R	3.5		ML 3.5 TAU
TASU	1968- 1-13	0508 29.0	144.980	-41.781	10.0 R	2.4		ML 2.4 TAU
TASU	1968- 1-19	0030 10.5	147.900	-43.565	10.0 R			
TASU	1968- 3- 7	2059 26.5	147.875	-43.578	10.0 R			
TASU	1968- 6-27	1547 35.0	147.440	-43.736	10.0 R			
TASU	1969- 3-10	1849 26.0	145.710	-43.300	10.0 R	2.5		ML 2.5 TAU
TASU	1969- 3-13	1128 12.0	144.750	-41.315	10.0 R	3.5		ML 3.5 TAU
TASU	1969- 3-19	2336 38.6	144.900	-41.450	10.0 R			
TASU	1969- 5-15	2331 57.0	146.416	-43.716	10.0 R	1.9		ML 1.9 TAU
TASU	1969- 6-28	1742 22.8	145.584	-42.766	10.0 R			
TASU	1969- 7-11	0010 21.0	146.410	-42.086	10.0 R			
TASU	1969- 7-27	0438 19.0	148.345	-42.161	10.0 R			

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TASU	1969- 8- 8	0822 22.1	146.767	-41.014	10.0 R			
TASU	1969- 8-26	1028 8.0	145.485	-42.979	10.0 R	2.6		ML 2.6 TAU
TASU	1969-11-25	1749 54.0	145.635	-42.980	10.0 R	2.1		ML 2.1 TAU
TASU	1970- 2-19	1156 48.8	145.610	-42.896	10.0 R			
TASU	1970- 6-15	0659 33.0	146.367	-43.017	10.0 R	2.2		ML 2.2 TAU
TASU	1970- 8-14	1435 11.0	146.404	-43.423	10.0 R	2.2		ML 2.2 TAU
TASU	1970- 9- 1	1048 24.9	146.636	-41.684	10.0 R			
TASU	1970- 9- 2	0156 47.0	146.920	-41.892	10.0 R			
TASU	1970- 9- 3	1235 0.0	146.146	-43.886	10.0 R	2.6		ML 2.6 TAU
TASU	1970- 9- 6	2316 29.1	146.730	-42.260	10.0 R			
TASU	1970-10- 4	2002 19.0	146.861	-42.240	10.0 R	1.5		ML 1.5 TAU
TASU	1970-10- 8	2105 40.3	145.865	-43.144	10.0 R	2.2		ML 2.2 TAU
TASU	1970-11-10	1917 55.6	145.848	-42.549	10.0 R	2.5		ML 2.5 TAU
TASU	1971- 1-14	0439 44.4	145.813	-43.052	10.0 R	1.5		ML 1.5 TAU
TASU	1971- 3- 2	1041 38.7	146.744	-42.630	10.0 R	1.8		ML 1.8 TAU
TASU	1971- 4-18	1041 9.6	146.105	-41.750	10.0 R	1.0		ML 1.0 TAU
TASU	1971- 5-21	0201 15.8	145.730	-43.100	10.0 R			
TASU	1971- 5-25	0254 55.2	146.100	-44.050	10.0 R	2.2		ML 2.2 TAU
TASU	1971- 6-10	1239 59.7	146.341	-42.831	10.0 R	2.0		ML 2.0 TAU
TASU	1971- 6-15	2006 24.7	145.834	-40.978	10.0 R	4.0		ML 4.0 TAU
TASU	1971- 6-17	0451 55.0	146.484	-42.233	10.0 R			
TASU	1971- 6-20	0303 52.6	145.780	-42.762	10.0 R	2.8		ML 2.8 TAU
TASU	1971- 7-18	1846 55.8	148.140	-43.270	10.0 R	2.3		ML 2.3 TAU
TASU	1971-11-15	1617 41.0	146.010	-42.450	10.0 R	1.8		ML 1.8 TAU
TASU	1971-11-29	2007 58.4	145.273	-42.275	10.0 R	1.9		ML 1.9 MEW
TASU	1971-12-18	1427 41.7	145.547	-42.918	10.0 R	2.1		ML 2.1 TAU
TASU	1971-12-19	0135 15.0	145.003	-41.300	10.0 R	2.0		ML 2.0 TAU
TASU	1971-12-19	0611 6.2	145.563	-42.940	10.0 R	1.6		ML 1.6 TAU
TASU	1972- 2-14	2005 38.4	145.396	-41.902	10.0 R	1.5		ML 1.5 TAU
TASU	1972- 2-14	2358 10.4	145.378	-41.914	10.0 R	2.0		ML 2.0 TAU
TASU	1972- 2-21	1144 4.0	145.396	-41.914	10.0 R	2.0		ML 2.0 TAU
TASU	1972- 2-23	0056 49.4	145.414	-41.905	10.0 R	1.6		ML 1.6 TAU
TASU	1972- 3- 4	1625 38.4	145.407	-41.929	10.0 R	3.0		ML 3.0 TAU
TASU	1972- 3- 4	1823 4.6	145.384	-41.924	10.0 R	1.3		ML 1.3 TAU
TASU	1972- 5-18	0503 14.6	146.021	-43.644	10.0 R	2.4		ML 2.4 TAU
TASU	1972- 7- 7	1053 51.7	147.420	-42.730	10.0 G	2.7		ML 2.7 TAU
TASU	1972- 7-28	1339 35.0	145.380	-41.920	10.0 G	1.7		ML 1.7 TAU
TASU	1972- 7-30	0447 51.0	145.800	-41.920	10.0 G	1.1		ML 1.1 TAU
TASU	1972- 7-30	0448 21.0	144.770	-41.120	10.0 G	1.5		ML 1.5 TAU
TASU	1972- 8- 2	0553 48.0	146.400	-42.630	10.0 G	1.6		ML 1.6 TAU
TASU	1972- 8-24	1230 34.0	145.700	-41.430	10.0 G	1.8		ML 1.8 TAU
TASU	1972- 9-10	1519 28.0	145.800	-42.120	10.0 G	1.7		ML 1.7 TAU
TASU	1972- 9-10	2315 33.7	145.150	-40.650	10.0 G	2.5		ML 2.5 TAU
TASU	1972- 9-18	1233 40.0	144.980	-41.230	10.0 G	2.7		ML 2.7 TAU
TASU	1972-10-13	0738 0.0	146.750	-44.330	10.0 G	2.5		ML 2.5 TAU
TASU	1972-10-19	0010 49.0	146.370	-42.870	10.0 G	2.3		ML 2.3 TAU
TASU	1972-10-21	0342 54.0	145.770	-42.400	10.0 G	1.5		ML 1.5 TAU
TASU	1972-11- 3	0359 0.5	146.400	-42.530	0.0 R	1.2		ML 1.2 TAU

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Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TASU	1972-11- 3	0827 46.0	145.450	-42.200	10.0 G	1.8		ML 1.8 TAU
TASU	1972-11-19	2232 44.0	145.450	-43.570	10.0 G	2.7		ML 2.7 TAU
TASU	1972-11-23	0703 12.2	145.910	-41.090	0.0 R	1.5		ML 1.5 TAU
TASU	1972-12-15	0212 20.0	146.170	-43.130	10.0 G	1.5		ML 1.5 TAU
TASU	1972-12-30	1051 6.3	148.450	-42.470	10.0 R	1.7		ML 1.7 TAU
TASU	1973- 1-11	1228 2.9	145.070	-42.080	0.0	1.3		ML 1.3 TAS
TASU	1973- 2-22	0647 20.1	145.470	-40.780	0.0	1.8		ML 1.8 TAS
TASU	1973- 3- 6	1214 36.5	148.280	-43.010	0.0	1.3		ML 1.3 TAS
TASU	1973- 3- 8	0852 16.8	147.730	-41.030	0.0	1.7		ML 1.7 TAS
TASU	1973- 3-10	1238 53.5	145.030	-40.650	0.0	2.1		ML 2.1 TAS
TASU	1973- 4- 5	1446 33.8	146.720	-42.870	0.0	1.2		ML 1.2 TAS
TASU	1973- 4- 9	1505 10.4	144.800	-42.100	0.0	2.4		ML 2.4 TAS
TASU	1973- 4-13	0345 18.9	146.930	-43.700	0.0	1.6		ML 1.6 TAS
TASU	1973- 4-14	0454 42.5	145.380	-42.770	0.0	1.0		ML 1.0 TAS
TASU	1973- 5-22	1351 4.7	145.480	-42.000	0.0	1.1		ML 1.1 TAS
TASU	1973- 5-24	1545 22.5	145.550	-42.400	0.0	2.7		ML 2.7 TAS
BMR	1973- 6- 3	1108 8.0	145.080	-42.320	10.0 G	4.0		ML 4.0 TOO
TASU	1973- 6-13	1801 6.6	145.370	-42.000	0.0	1.5		ML 1.5 TAS
BMR	1973- 8-31	0404 44.1	145.910	-42.860	10.0 G			
TASU	1973- 9- 3	1208 54.0	146.380	-42.880	0.0	1.5		ML 1.5 TAS
TASU	1973- 9- 3	1808 18.7	147.520	-42.170	0.0	1.4		ML 1.4 TAS
TASU	1973- 9-11	0037 27.7	146.470	-42.450	0.0	1.2		ML 1.2 TAS
TASU	1973- 9-13	2238 41.1	144.850	-42.420	0.0	2.5		ML 2.5 TAS
TASU	1973- 9-18	0955 44.6	147.010	-42.950	0.0	1.2		ML 1.2 TAS
TASU	1973-10- 6	1101 16.4	145.630	-42.350	0.0	1.2		ML 1.2 TAS
TASU	1973-10- 6	2217 21.8	148.220	-42.450	0.0	1.6		ML 1.6 TAS
TASU	1973-11- 7	1513 25.0	146.350	-43.670	0.0	1.8		ML 1.8 TAS
TASU	1973-12- 8	0801 50.4	146.750	-43.030	0.0	1.4		ML 1.4 TAS
TASU	1974- 1- 5	1347 8.9	145.640	-42.790	14.0 R	1.9		ML 1.9 TAU
TASU	1974- 2- 1	2020 14.5	146.030	-43.020	10.0			
TASU	1974- 2-11	1049 33.5	146.920	-43.700	10.0	2.2		ML 2.2 TAU
TASU	1974- 2-24	1223 32.0	146.680	-42.390	16.0			
TASU	1974- 2-25	1001 56.8	144.760	-41.460	10.0	2.8		ML 2.8 TAU
TASU	1974- 3-10	1635 7.6	146.060	-42.750	0.0 R	1.3		ML 1.3 TAU
TASU	1974- 3-12	2339 9.8	147.120	-43.160	0.0			
TASU	1974- 3-24	2310 13.8	145.700	-42.700	0.0	1.3		ML 1.3 TAU
TASU	1974- 4- 1	0751 12.1	147.160	-43.250	17.0			
TASU	1974- 4- 1	0752 14.3	147.140	-43.180	1.0	1.3		ML 1.3 TAU
TASU	1974- 4- 3	1125 9.8	146.290	-41.770	9.0	2.0		ML 2.0 TAU
TASU	1974- 4- 9	0634 4.1	146.210	-42.750	0.0			
TASU	1974- 4-15	1038 30.0	147.700	-41.450	10.0			
TASU	1974- 4-23	0932 16.5	146.310	-42.880	0.0 R			
TASU	1974- 4-26	1436 27.9	146.280	-42.610	10.0			
TASU	1974- 5-17	0949 23.2	146.870	-40.950	10.0			
TASU	1974- 7- 5	0829 16.9	148.150	-42.117	0.0			
TASU	1974- 7-10	1649 20.5	146.500	-42.650	0.0			
TASU	1974- 7-12	1113 16.1	145.383	-42.867	0.0			
TASU	1974- 7-15	0618 36.0	146.817	-43.367	0.0			

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TASU	1974- 8- 9	0152 29.0	147.067	-42.017	0.0			
TASU	1974- 8-30	2035 55.5	148.117	-42.233	0.0			
TASU	1974- 9- 1	1142 59.6	145.467	-42.850	0.0			
TASU	1974- 9- 3	1606 33.6	145.367	-42.267	0.0			
TASU	1974- 9- 9	0137 58.3	145.867	-42.883	0.0			
TASU	1974- 9-20	1724 49.7	146.817	-42.350	0.0			
TASU	1974-10- 2	1543 55.2	147.017	-43.533	0.0			
TASU	1974-10- 2	1742 23.1	147.117	-43.483	0.0			
TASU	1974-10- 6	0821 8.7	144.833	-40.867	0.0			
TASU	1974-10-22	1544 12.3	145.967	-42.350	0.0			
TASU	1974-10-30	2358 39.1	146.750	-43.267	0.0			
TASU	1974-11-16	1507 26.2	146.250	-40.750	0.0			
TASU	1974-12- 5	1544 29.1	146.533	-43.000	0.0			
TASU	1974-12-26	1040 56.6	145.117	-42.317	0.0	2.0		ML 2.0 TAU
TASU	1974-12-28	0507 40.7	145.800	-42.550	0.0	0.5		ML 0.5 TAU
TASU	1975- 1- 3	1303 1.3	145.717	-41.067	0.0	2.0		ML 2.0 TAU
TASU	1975- 1-22	1153 21.8	146.383	-42.567	0.0	1.5		ML 1.5 TAU
TASU	1975- 2-21	1403 24.3	145.433	-40.833	0.0	1.5		ML 1.5 TAU
TASU	1975- 2-27	0254 25.9	148.150	-42.133	0.0			
TASU	1975- 3- 2	2304 41.1	146.233	-42.917	0.0			
TASU	1975- 3- 7	1042 24.8	146.400	-42.883	0.0			
TASU	1975- 3-16	0734 47.5	146.300	-42.900	0.0			
TASU	1975- 5-10	1114 13.3	144.700	-40.700	0.0	2.5		ML 2.5 TAU
TASU	1975- 5-15	0300 8.7	146.133	-42.700	0.0	1.0		ML 1.0 TAU
TASU	1975- 5-17	1207 49.6	146.117	-42.700	0.0			
TASU	1975- 5-22	1358 37.8	145.700	-42.967	0.0	1.0		ML 1.0 TAU
TASU	1975- 5-22	1740 7.5	146.150	-42.667	0.0	1.5		ML 1.5 TAU
TASU	1975- 5-29	1739 55.9	146.317	-43.417	0.0			
TASU	1975- 6-17	1117 47.7	147.167	-43.533	0.0	1.5		ML 1.5 TAU
TASU	1975- 6-18	1617 50.1	148.117	-43.367	0.0			
TASU	1975- 7- 2	1212 27.5	146.350	-42.950	0.0			
TASU	1975- 7-18	1057 10.8	146.567	-41.733	0.0	1.6		ML 1.6 TAU
TASU	1975- 7-24	1802 34.0	145.667	-42.067	0.0	0.5		ML 0.5 TAU
TASU	1975- 8- 1	1732 22.3	147.417	-42.067	0.0	2.0		ML 2.0 TAU
TASU	1975- 8- 9	0117 40.2	145.550	-42.883	0.0	1.5		ML 1.5 TAU
TASU	1975- 8-20	0104 2.0	145.500	-42.800	0.0	2.5		ML 2.5 TAU
TASU	1975- 9-11	1844 21.8	146.933	-42.467	0.0	1.5		ML 1.5 TAU
TASU	1975- 9-23	1352 33.8	147.550	-43.083	0.0	1.5		ML 1.5 TAU
TASU	1975- 9-30	0600 36.5	145.400	-42.033	0.0			
TASU	1975- 9-30	1306 9.2	145.300	-43.350	0.0	2.5		ML 2.5 TAU
TASU	1975-10- 2	1349 11.9	144.983	-42.167	0.0	1.5		ML 1.5 TAU
TASU	1975-10-15	0432 48.7	146.533	-42.600	0.0	0.5		ML 0.5 TAU
TASU	1975-10-16	1042 35.2	145.717	-43.167	0.0			
TASU	1975-10-18	1614 49.4	146.267	-42.567	0.0	0.5		ML 0.5 TAU
TASU	1975-10-19	0855 40.7	148.117	-43.567	0.0	1.5		ML 1.5 TAU
TASU	1975-11- 6	0858 33.8	145.517	-42.050	0.0	1.5		ML 1.5 TAU
BMR	1975-11- 8	0535 59.5	144.840	-40.650	10.0	2.7		ML 2.7 TGO
TASU	1975-11-21	0919 8.8	145.467	-42.833	0.0	1.8		ML 1.8 TAU

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Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TASU	1975-11-22	0027 14.8	146.133	-43.050	0.0			
TASU	1975-11-22	1939 3.7	146.217	-43.000	0.0			
TASU	1975-12- 6	0430 33.2	146.583	-43.000	0.0	2.0		ML 2.0 TAU
TASU	1975-12- 8	0743 13.3	146.333	-43.350	0.0	1.5		ML 1.5 TAU
TASU	1975-12-12	1709 29.8	148.200	-42.183	0.0	2.2		ML 2.2 TAU
TASU	1975-12-14	1549 43.0	147.300	-42.433	0.0	2.0		ML 2.0 TAU
TASU	1975-12-19	1714 58.6	145.270	-40.570	0.0	2.3		ML 2.3 TAU
TASU	1975-12-23	0622 27.5	146.000	-42.820	0.0	1.0		ML 1.0 TAU
TASU	1975-12-25	0702 13.2	147.220	-43.320	0.0	1.6		ML 1.6 TAU
TASU	1976- 1- 1	0857 12.7	146.550	-41.850	0.0	1.0		ML 1.0 TAU
TASU	1976- 1- 6	1144 44.5	147.250	-40.880	0.0	1.0		ML 1.0 TAU
TASU	1976- 1- 8	1529 14.3	144.880	-41.660	0.0	2.0		ML 2.0 TAU
TASU	1976- 1-28	0035 44.0	144.700	-41.630	0.0	2.0		ML 2.0 TAU
TASU	1976- 2-12	0205 4.1	148.500	-40.750	0.0	2.0		ML 2.0 TAU
TASU	1976- 2-12	1526 41.0	148.500	-40.580	0.0	2.0		ML 2.0 TAU
TASU	1976- 3-23	1056 6.4	147.100	-42.400	0.0	1.5		ML 1.5 TAU
TASU	1976- 3-23	2145 49.9	147.000	-42.400	0.0	1.3		ML 1.3 TAU
TASU	1976- 3-31	2005 59.6	146.220	-42.620	0.0	1.0		ML 1.0 TAU
TASU	1976- 4-12	0649 25.0	144.880	-41.380	0.0	2.0		ML 2.0 TAU
TASU	1976- 4-14	0206 40.6	145.600	-41.730	0.0	1.5		ML 1.5 TAU
TASU	1976- 5- 9	1314 15.8	145.340	-41.500	0.0	2.3		ML 2.3 TAU
TASU	1976- 5-12	0804 13.7	146.070	-40.570	0.0	1.8		ML 1.8 TAU
TASU	1976- 5-23	2118 50.9	145.600	-42.930	0.0	1.5		ML 1.5 TAU
TASU	1976- 5-27	0524 39.2	146.430	-42.470	0.0	1.0		ML 1.0 TAU
TASU	1976- 6- 2	1458 1.5	144.980	-40.990	0.0	1.9		ML 1.9 TAU
TASU	1976- 7- 2	1441 37.8	147.070	-42.050	0.0	2.8		ML 2.8 TAU
TASU	1976- 7-11	1053 15.9	146.300	-42.700	0.0	1.0		ML 1.0 TAU
BMR	1976- 7-11	1258 6.1	146.190	-40.800	32.0	2.6		ML 2.6 TGO
TASU	1976- 7-11	1615 6.9	146.280	-41.120	0.0	1.5		ML 1.5 TAU
TASU	1976- 7-28	0620 49.8	146.580	-43.050	0.0	1.0		ML 1.0 TAU
TASU	1976- 8- 3	0103 21.4	147.580	-42.200	0.0	1.7		ML 1.7 TAU
TASU	1976- 8-18	1517 12.5	148.430	-42.490	0.0	1.2		ML 1.2 TAU
TASU	1976- 9- 4	1805 4.2	146.200	-42.870	0.0	1.3		ML 1.3 TAU
TASU	1976- 9- 5	0710 3.2	146.230	-42.830	0.0	1.8		ML 1.8 TAU
TASU	1976- 9- 5	1757 15.5	146.150	-42.750	0.0	1.0		ML 1.0 TAU
TASU	1976- 9- 8	1744 30.5	148.170	-43.100	0.0	1.9		ML 1.9 TAU
TASU	1976- 9-11	0718 11.0	148.500	-43.780	0.0	1.7		ML 1.7 TAU
TASU	1976- 9-14	2334 28.7	146.170	-42.670	0.0	1.3		ML 1.3 TAU
TASU	1976- 9-15	2241 27.8	146.800	-42.870	0.0	1.7		ML 1.7 TAU
TASU	1976- 9-24	2107 51.0	146.670	-43.530	0.0	1.0		ML 1.0 TAU
TASU	1976-10- 5	0508 0.3	145.630	-42.630	0.0	1.0		ML 1.0 TAU
TASU	1976-10-16	1706 45.3	145.830	-42.180	0.0	2.7		ML 2.7 TAU
TASU	1976-10-19	0448 36.4	146.780	-43.380	0.0	1.4		ML 1.4 TAU
TASU	1976-10-21	0030 18.2	145.670	-40.510	0.0	1.8		ML 1.8 TAU
TASU	1976-10-21	2333 19.3	146.150	-42.650	0.0	1.4		ML 1.4 TAU
TASU	1976-10-22	0046 40.0	145.780	-40.670	0.0	2.0		ML 2.0 TAU
TASU	1976-10-28	1221 46.9	146.080	-42.870	0.0	1.0		ML 1.0 TAU
TASU	1976-11- 3	0242 41.0	146.070	-42.630	0.0	2.0		ML 2.0 TAU

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Srce	UT Date	Time		Long	Lat	Depth	eML	Surface	Local		
TASU	1976-11-24	1649	43.2	148.050	-42.100	0.0	2.0		ML	2.0	TAU
TASU	1976-11-25	0609	25.4	145.550	-41.620	0.0	1.5		ML	1.5	TAU
TASU	1976-11-25	0754	15.4	148.300	-41.830	0.0	2.0		ML	2.0	TAU
TASU	1976-11-26	0645	58.7	145.120	-40.820	0.0	2.5		ML	2.5	TAU
TASU	1976-11-26	2050	44.1	145.620	-42.500	0.0	1.2		ML	1.2	TAU
TASU	1976-12- 8	1013	21.4	148.280	-42.080	0.0	1.7		ML	1.7	TAU
TASU	1976-12- 9	0702	40.5	146.050	-42.600	0.0	1.4		ML	1.4	TAU
TAU	1976-12-17	0513	19.5	146.700	-43.120	0.0	1.5		ML	1.5	TAU
TAU	1976-12-20	0237	25.8	145.950	-43.130	0.0	2.3		ML	2.3	TAU
TAU	1976-12-20	1644	16.2	145.500	-42.800	0.0	1.4		ML	1.4	TAU
TAU	1976-12-21	0837	55.8	146.040	-43.000	0.0	2.6		ML	2.6	TAU
TAU	1976-12-21	1100	58.3	146.200	-42.180	0.0	1.0		ML	1.0	TAU
TAU	1976-12-21	1206	44.2	146.330	-43.670	0.0	2.0		ML	2.0	TAU
TAU	1976-12-21	2001	44.8	146.200	-42.150	0.0	1.0		ML	1.0	TAU
TAU	1976-12-26	1544	18.3	146.530	-41.530	0.0	1.1		ML	1.1	TAU
TAU	1977- 1- 4	2324	16.9	145.420	-42.650	0.0	1.5		ML	1.5	TAU
TAU	1977- 1- 9	0118	40.4	145.220	-42.600	0.0	1.9		ML	1.9	TAU
TAU	1977- 1-11	0141	50.3	146.870	-43.630	0.0	1.2		ML	1.2	TAU
TAU	1977- 1-12	1543	14.1	145.170	-40.550	0.0	2.3		ML	2.3	TAU
TAU	1977- 1-13	1325	14.7	147.270	-42.100	0.0	1.2		ML	1.2	TAU
TAU	1977- 1-13	2212	9.1	145.380	-41.820	0.0	1.5		ML	1.5	TAU
TAU	1977- 1-24	1810	57.1	145.670	-42.870	0.0	2.0		ML	2.0	TAU
TAU	1977- 1-31	0116	1.9	148.050	-42.120	0.0	2.0		ML	2.0	TAU
TAU	1977- 2-16	0158	33.8	147.250	-43.550	0.0	1.3		ML	1.3	TAU
TAU	1977- 2-17	0241	6.7	148.130	-43.300	0.0	1.5		ML	1.5	TAU
TAU	1977- 2-28	0149	44.6	146.300	-41.680	0.0	1.3		ML	1.3	TAU
TAU	1977- 3-26	0446	12.6	146.120	-42.830	0.0	1.0		ML	1.0	TAU
TAU	1977- 4-10	0705	19.7	144.920	-41.620	0.0	1.6		ML	1.6	TAU
TAU	1977- 5- 1	1336	51.2	146.070	-42.600	0.0	1.1		ML	1.1	TAU
TAU	1977- 5-10	0642	49.4	146.680	-43.570	0.0	1.0		ML	1.0	TAU
TAU	1977- 5-11	1018	13.2	145.400	-41.920	0.0	2.2		ML	2.2	TAU
TAU	1977- 5-11	1056	11.3	145.570	-41.930	0.0	1.5		ML	1.5	TAU
TAU	1977- 5-12	0928	38.8	144.570	-42.070	0.0	2.1		ML	2.1	TAU
TAU	1977- 5-13	1845	3.4	144.580	-41.320	0.0	2.5		ML	2.5	TAU
TAU	1977- 5-14	0833	5.0	145.080	-40.570	0.0	2.0		ML	2.0	TAU
TAU	1977- 5-15	0944	43.2	144.700	-41.350	0.0	2.1		ML	2.1	TAU
TAU	1977- 5-19	0037	28.1	145.830	-43.550	0.0	1.0		ML	1.0	TAU
TAU	1977- 5-20	0644	11.1	146.970	-43.830	0.0	2.0		ML	2.0	TAU
TAU	1977- 5-23	2323	17.4	146.250	-42.800	0.0	0.7		ML	0.7	TAU
TAU	1977- 6- 3	0629	11.0	146.830	-43.470	0.0	1.7		ML	1.7	TAU
TAU	1977- 6- 3	1710	2.5	147.100	-43.620	0.0	1.8		ML	1.8	TAU
TAU	1977- 6- 4	0841	4.8	146.580	-40.620	0.0	2.0		ML	2.0	TAU
TAU	1977- 6- 8	0211	55.6	144.520	-42.480	0.0	1.5		ML	1.5	TAU
TAU	1977- 6-11	2213	32.8	145.580	-40.820	0.0	1.9		ML	1.9	TAU
TAU	1977- 7- 1	1313	40.5	145.580	-41.580	0.0	1.0		ML	1.0	TAU
TAU	1977- 7- 3	2203	5.1	145.800	-43.100	0.0	1.5		ML	1.5	TAU
TAU	1977- 7-11	0627	32.6	146.770	-43.470	0.0	1.5		ML	1.5	TAU
TAU	1977- 7-20	0048	27.4	146.430	-42.630	0.0	1.3		ML	1.3	TAU

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time		Long	Lat	Depth	eML	Surface	Local		
TAU	1977- 7-20	1032	19.1	146.030	-43.750	0.0	1.5		ML	1.5	TAU
TAU	1977- 7-20	1722	41.1	146.830	-43.630	0.0	2.0		ML	2.0	TAU
TAU	1977- 7-24	2137	50.6	144.500	-40.830	0.0	2.6		ML	2.6	TAU
TAU	1977- 7-30	1438	52.9	145.550	-42.780	0.0	1.2		ML	1.2	TAU
TAU	1977- 8- 5	2308	20.6	145.570	-42.500	0.0	1.0		ML	1.0	TAU
TAU	1977- 8-11	1623	27.8	145.620	-43.470	0.0	1.6		ML	1.6	TAU
TAU	1977- 8-11	1752	49.6	144.680	-40.580	0.0	1.7		ML	1.7	TAU
TAU	1977- 9- 2	1849	30.5	146.170	-41.550	0.0	1.6		ML	1.6	TAU
TAU	1977- 9- 5	1306	8.8	145.920	-40.770	0.0	1.5		ML	1.5	TAU
TAU	1977- 9-24	1530	43.0	147.020	-41.500	0.0	2.7		ML	2.7	TAU
TAU	1977- 9-28	1650	5.5	145.050	-40.970	0.0	1.6		ML	1.6	TAU
TAU	1977-10- 4	1910	10.9	146.100	-42.870	0.0	1.0		ML	1.0	TAU
TAU	1977-10-20	0248	55.5	147.020	-43.900	0.0	1.8		ML	1.8	TAU
TAU	1977-11- 9	1335	35.7	145.150	-40.870	0.0	2.0		ML	2.0	TAU
TAU	1977-11-15	0358	42.9	146.500	-42.470	0.0	1.6		ML	1.6	TAU
TAU	1977-11-27	0111	23.3	145.380	-40.870	0.0	2.4		ML	2.4	TAU
TAU	1977-12- 1	0147	43.0	146.400	-41.500	0.0	1.2		ML	1.2	TAU
TAU	1977-12- 5	1224	11.2	146.180	-42.770	0.0	1.2		ML	1.2	TAU
TAU	1977-12- 8	0610	34.7	145.780	-41.150	0.0	2.0		ML	2.0	TAU
TAU	1977-12- 9	0844	28.3	144.830	-41.000	0.0	1.6		ML	1.6	TAU
TAU	1977-12-10	0239	30.7	145.030	-41.550	0.0	1.6		ML	1.6	TAU
TAU	1977-12-11	1205	6.8	146.200	-41.580	0.0	1.4		ML	1.4	TAU
TAU	1977-12-13	1218	8.7	145.500	-43.420	0.0	1.5		ML	1.5	TAU
TAU	1977-12-17	2151	51.4	145.930	-40.500	0.0	2.0		ML	2.0	TAU
TAU	1977-12-21	0852	55.0	145.450	-42.000	0.0	1.8		ML	1.8	TAU
TAU	1977-12-21	1102	56.4	146.080	-42.980	0.0	3.0		ML	3.0	TAU
TAU	1977-12-23	0908	44.2	145.950	-42.960	0.0	1.0		ML	1.0	TAU
TAU	1977-12-28	1654	36.1	145.780	-42.260	0.0	1.4		ML	1.4	TAU
TAU	1978- 1- 2	1302	2.3	145.800	-42.280	0.0	1.7		ML	1.7	TAU
TAU	1978- 1-13	0635	13.8	144.930	-41.260	0.0	2.0		ML	2.0	TAU
TAU	1978- 1-14	1437	56.8	144.560	-41.080	0.0	2.0		ML	2.0	TAU
TAU	1978- 1-24	2148	24.4	146.220	-42.660	0.0	2.0		ML	2.0	TAU
TAU	1978- 2- 2	1011	50.7	146.950	-42.520	0.0	2.1		ML	2.1	TAU
TAU	1978- 2- 4	0914	10.9	145.200	-42.830	0.0	2.1		ML	2.1	TAU
TAU	1978- 2- 5	0813	43.8	146.360	-43.900	0.0	2.0		ML	2.0	TAU
TAU	1978- 2- 5	2252	38.9	145.380	-40.630	0.0	2.0		ML	2.0	TAU
TAU	1978- 2-17	0224	2.5	147.030	-41.470	0.0	1.0		ML	1.0	TAU
TAU	1978- 2-17	0236	3.6	146.430	-41.520	0.0	1.0		ML	1.0	TAU
TAU	1978- 2-17	0404	11.8	147.920	-43.170	0.0	1.5		ML	1.5	TAU
TAU	1978- 2-18	0456	36.6	145.530	-42.070	0.0	1.9		ML	1.9	TAU
TAU	1978- 2-18	1609	2.7	145.950	-42.450	0.0	1.0		ML	1.0	TAU
TAU	1978- 2-20	1307	34.6	146.790	-43.730	0.0	1.6		ML	1.6	TAU
TAU	1978- 2-21	1610	0.2	145.520	-42.780	0.0	1.6		ML	1.6	TAU
TAU	1978- 2-27	2212	11.0	148.120	-41.630	0.0	1.9		ML	1.9	TAU
TAU	1978- 3- 4	1512	12.1	144.980	-40.600	0.0	2.1		ML	2.1	TAU
TAU	1978- 3- 9	2153	7.6	146.120	-42.700	0.0	1.0		ML	1.0	TAU
TAU	1978- 3-13	1531	12.5	145.830	-42.650	0.0	1.5		ML	1.5	TAU
TAU	1978- 3-27	0317	45.2	147.070	-42.080	0.0	1.9		ML	1.9	TAU

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Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TAU	1978- 3-30	1055 16.3	146.180	-42.350	0.0	1.5		ML 1.5 TAU
TAU	1978- 4-13	2308 47.8	146.310	-42.920	0.0	1.7		ML 1.7 TAU
TAU	1978- 4-19	1746 34.6	145.570	-43.950	0.0	2.6		ML 2.6 TAU
TAU	1978- 4-22	1330 51.0	147.000	-42.950	0.0	1.3		ML 1.3 TAU
TAU	1978- 5- 3	1727 3.5	145.770	-41.000	0.0	2.5		ML 2.5 TAU
TAU	1978- 5- 4	1123 46.0	146.230	-42.730	0.0	1.0		ML 1.0 TAU
BMR	1978- 5- 4	1134 52.4	145.680	-41.020	12.0	3.0		ML 3.0 BFD
TAU	1978- 5- 6	1203 6.8	145.750	-43.750	0.0	1.6		ML 1.6 TAU
TAU	1978- 5-12	2353 4.2	144.970	-41.450	0.0	2.0		ML 2.0 TAU
TAU	1978- 5-20	1914 18.9	146.080	-43.020	0.0	1.0		ML 1.0 TAU
TAU	1978- 5-26	0334 5.9	146.570	-42.870	0.0	1.3		ML 1.3 TAU
TAU	1978- 6- 2	1705 24.4	146.270	-42.820	0.0	1.5		ML 1.5 TAU
TAU	1978- 6- 3	1457 2.2	146.170	-42.750	0.0	1.5		ML 1.5 TAU
TAU	1978- 6- 7	1421 3.0	148.070	-42.100	0.0	1.9		ML 1.9 TAU
TAU	1978- 6- 8	1417 29.8	144.770	-42.880	0.0	2.2		ML 2.2 TAU
TAU	1978- 6-14	0120 38.3	146.950	-41.350	0.0	1.5		ML 1.5 TAU
TAU	1978- 6-17	2130 42.1	146.070	-42.480	0.0	1.2		ML 1.2 TAU
TAU	1978- 6-24	0910 51.1	145.580	-42.050	0.0	2.1		ML 2.1 TAU
TAU	1978- 6-30	2038 34.5	144.750	-41.280	0.0	1.6		ML 1.6 TAU
TAU	1978- 7-18	1339 59.1	146.770	-43.800	0.0	2.0		ML 2.0 TAU
TAU	1978- 7-19	1524 21.8	146.050	-42.850	0.0	1.0		ML 1.0 TAU
TAU	1978- 7-29	1550 21.0	146.980	-42.420	0.0	1.0		ML 1.0 TAU
TAU	1978- 8- 4	0634 51.7	146.250	-42.720	0.0	1.6		ML 1.6 TAU
TAU	1978- 8-25	0019 46.0	145.780	-42.980	20.0	3.0		ML 3.0 TAU
TAU	1978- 8-27	1221 31.6	145.850	-43.000	0.0	1.3		ML 1.3 TAU
TAU	1978- 9- 1	1355 24.0	145.700	-40.570	0.0	1.7		ML 1.7 TAU
TAU	1978- 9- 8	0431 19.0	146.130	-42.720	0.0	1.5		ML 1.5 TAU
TAU	1978- 9-12	1303 59.1	145.870	-42.520	0.0	1.3		ML 1.3 TAU
TAU	1978- 9-23	1517 42.1	145.330	-42.850	0.0	1.8		ML 1.8 TAU
TAU	1978-10- 6	0302 58.1	146.280	-42.870	0.0	1.8		ML 1.8 TAU
TAU	1978-10-15	1913 6.1	145.080	-40.920	0.0	1.8		ML 1.8 TAU
TAU	1978-10-20	0052 48.0	147.880	-42.680	0.0	2.7		ML 2.7 TAU
TAU	1978-10-20	0057 40.9	147.880	-42.670	0.0	1.9		ML 1.9 TAU
TAU	1978-10-20	0240 14.3	147.800	-42.650	0.0	1.5		ML 1.5 TAU
TAU	1978-10-26	2211 15.1	144.770	-42.400	0.0	2.6		ML 2.6 TAU
TAU	1978-11-21	0316 33.3	146.350	-43.370	0.0	1.7		ML 1.7 TAU
TAU	1978-11-22	0533 2.1	146.300	-41.700	0.0	1.6		ML 1.6 TAU
TAU	1978-12- 2	1854 51.4	145.050	-42.730	0.0	1.7		ML 1.7 TAU
TAU	1978-12- 3	2334 42.9	147.950	-42.680	0.0	1.3		ML 1.3 TAU
TAU	1978-12-13	1921 10.1	147.750	-42.570	0.0	1.6		ML 1.6 TAU
TAU	1979- 1- 2	1534 34.1	146.120	-42.830	0.0	1.4		ML 1.4 TAU
TAU	1979- 1- 5	1133 12.9	146.420	-41.120	0.0	1.7		ML 1.7 TAU
TAU	1979- 1- 5	1304 15.7	146.920	-42.550	0.0	0.9		ML 0.9 TAU
TAU	1979- 1-20	1128 48.9	146.380	-43.180	0.0	1.0		ML 1.0 TAU
TAU	1979- 1-21	0225 27.5	144.780	-42.280	0.0	1.5		ML 1.5 TAU
TAU	1979- 2-22	0333 35.9	146.570	-41.150	0.0	1.8		ML 1.8 TAU
TAU	1979- 2-24	0824 14.3	147.750	-43.520	0.0	2.0		ML 2.0 TAU
TAU	1979- 2-24	1827 2.3	146.870	-43.980	0.0	1.3		ML 1.3 TAU

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Select events with:
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Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TAU	1979- 2-27	0602 11.3	147.080	-40.950	0.0	1.9		ML 1.9 TAU
TAU	1979- 2-28	0353 2.6	144.650	-41.370	0.0	1.9		ML 1.9 TAU
TAU	1979- 3- 2	0333 10.1	146.170	-42.720	0.0	1.2		ML 1.2 TAU
TAU	1979- 3- 4	1613 4.9	146.270	-42.680	0.0	1.3		ML 1.3 TAU
TAU	1979- 3- 7	0208 52.5	145.300	-41.550	0.0	1.6		ML 1.6 TAU
TAU	1979- 3-17	0053 25.3	146.250	-42.680	0.0	2.0		ML 2.0 TAU
TAU	1979- 3-22	2134 15.6	146.220	-42.730	0.0	1.0		ML 1.0 TAU
TAU	1979- 3-23	0731 28.4	147.070	-43.270	0.0	1.6		ML 1.6 TAU
TAU	1979- 4- 1	0936 17.0	146.370	-42.870	0.0	1.0		ML 1.0 TAU
TAU	1979- 4- 9	1450 19.6	145.650	-40.980	0.0	1.6		ML 1.6 TAU
TAU	1979- 4-11	0136 6.5	145.680	-42.900	0.0	1.7		ML 1.7 TAU
TAU	1979- 4-11	2242 54.4	145.720	-42.780	0.0	1.2		ML 1.2 TAU
TAU	1979- 4-26	0020 44.2	144.870	-41.330	0.0	2.4		ML 2.4 TAU
TAU	1979- 5- 1	1004 44.4	146.150	-43.070	0.0	2.0		ML 2.0 TAU
TAU	1979- 5- 7	0333 45.4	145.600	-42.870	0.0	1.4		ML 1.4 TAU
TAU	1979- 5-18	2241 49.5	146.550	-43.470	0.0	1.4		ML 1.4 TAU
TAU	1979- 6- 1	1202 13.4	145.980	-42.480	0.0	1.3		ML 1.3 TAU
TAU	1979- 6-20	0658 38.8	145.270	-42.880	0.0	1.4		ML 1.4 TAU
TAU	1979- 6-26	0623 9.3	146.900	-43.550	0.0	1.8		ML 1.8 TAU
TAU	1979- 7- 9	0547 4.9	148.500	-41.700	0.0	2.7		ML 2.7 TAU
TAU	1979- 7-14	1941 17.0	146.650	-42.330	0.0	1.9		ML 1.9 TAU
TAU	1979- 7-15	1425 3.4	146.680	-42.370	0.0	2.0		ML 2.0 TAU
TAU	1979- 7-16	1041 36.5	146.650	-42.420	0.0	1.0		ML 1.0 TAU
TAU	1979- 7-20	1858 30.7	145.650	-41.630	0.0	2.1		ML 2.1 TAU
TAU	1979- 7-28	2121 4.0	144.720	-40.520	0.0	3.0		ML 3.0 TAU
TAU	1979- 8- 2	0401 18.3	146.070	-42.850	0.0	0.9		ML 0.9 TAU
TAU	1979- 8- 4	1328 46.1	147.020	-41.730	0.0	0.9		ML 0.9 TAU
TAU	1979- 8- 7	0237 2.0	146.870	-43.470	0.0	1.5		ML 1.5 TAU
TAU	1979- 8-17	0426 45.6	146.950	-43.450	0.0	2.4		ML 2.4 TAU
TAU	1979- 8-21	0548 15.8	146.800	-43.500	0.0	1.5		ML 1.5 TAU
TAU	1979- 9-17	1801 15.3	146.600	-43.230	0.0	2.0		ML 2.0 TAU
TAU	1979- 9-21	0950 5.0	148.450	-42.700	0.0	2.0		ML 2.0 TAU
TAU	1979-10- 2	1438 20.6	145.750	-42.720	0.0	1.2		ML 1.2 TAU
TAU	1979-11- 8	0028 55.9	146.100	-42.200	0.0	1.3		ML 1.3 TAU
TAU	1979-11- 9	0148 24.4	147.370	-42.280	0.0	0.9		ML 0.9 TAU
TAU	1979-11-21	0435 23.5	146.820	-43.480	0.0	1.7		ML 1.7 TAU
TAU	1979-11-25	1416 44.2	146.980	-41.930	0.0	1.2		ML 1.2 TAU
TAU	1979-11-26	0913 0.7	145.170	-40.580	0.0	2.3		ML 2.3 TAU
TAU	1979-11-26	1501 8.1	145.320	-40.770	0.0	1.5		ML 1.5 TAU
TAU	1979-12- 6	1236 58.4	145.180	-40.670	0.0	2.4		ML 2.4 TAU
TAU	1979-12- 7	0448 29.4	146.450	-42.500	0.0	1.2		ML 1.2 TAU
TAU	1979-12-15	0613 53.4	146.070	-43.030	0.0	2.0		ML 2.0 TAU
TAU	1979-12-19	0525 27.4	146.800	-43.380	0.0	1.6		ML 1.6 TAU
TAU	1980- 1- 2	2002 35.8	146.120	-42.800	0.0	1.0		ML 1.0 TAU
TAU	1980- 1-16	1136 27.2	146.610	-43.380	0.0	1.1		ML 1.1 TAU
TAU	1980- 1-16	1250 27.1	145.500	-42.050	0.0	1.4		ML 1.4 TAU
TAU	1980- 1-28	1710 54.1	146.120	-42.750	0.0	1.4		ML 1.4 TAU
TAU	1980- 1-28	2345 51.9	145.500	-42.770	0.0	1.6		ML 1.6 TAU

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Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time		Long	Lat	Depth	eML	Surface	Local		
TAU	1980- 2-10	1457	49.6	148.000	-44.100	0.0	1.7		ML	1.7	TAU
TAU	1980- 2-15	0914	26.0	145.900	-42.610	0.0	1.3		ML	1.3	TAU
TAU	1980- 2-16	1313	1.5	146.620	-43.000	0.0	1.0		ML	1.0	TAU
TAU	1980- 2-22	1058	3.4	146.160	-42.650	0.0	1.8		ML	1.8	TAU
TAU	1980- 3- 3	0701	41.6	145.530	-42.270	0.0	1.5		ML	1.5	TAU
TAU	1980- 3- 5	0652	35.2	146.560	-43.100	0.0	1.1		ML	1.1	TAU
TAU	1980- 3- 5	0741	35.0	146.530	-42.520	0.0	1.1		ML	1.1	TAU
TAU	1980- 3- 7	2338	36.9	145.920	-42.800	0.0	1.5		ML	1.5	TAU
TAU	1980- 3- 7	2356	25.0	147.280	-42.180	0.0	1.5		ML	1.5	TAU
TAU	1980- 3-11	1152	8.6	146.270	-42.650	0.0	1.0		ML	1.0	TAU
TAU	1980- 3-22	0812	1.5	146.420	-42.880	0.0	1.0		ML	1.0	TAU
TAU	1980- 4- 8	0228	14.0	146.350	-41.870	0.0	1.2		ML	1.2	TAU
TAU	1980- 4- 8	0755	8.2	146.450	-42.500	0.0	1.3		ML	1.3	TAU
TAU	1980- 4- 9	0149	16.8	146.170	-42.820	0.0	1.5		ML	1.5	TAU
TAU	1980- 4- 9	1216	57.1	145.400	-42.970	0.0	1.4		ML	1.4	TAU
TAU	1980- 4-10	0956	19.6	148.130	-43.680	0.0	2.0		ML	2.0	TAU
TAU	1980- 4-11	0354	59.4	147.830	-43.080	0.0	1.0		ML	1.0	TAU
TAU	1980- 4-13	1318	19.8	148.350	-41.730	0.0	1.7		ML	1.7	TAU
TAU	1980- 4-16	2018	46.4	145.510	-42.250	0.0	1.1		ML	1.1	TAU
TAU	1980- 4-22	2312	34.5	146.230	-42.970	0.0	1.0		ML	1.0	TAU
TAU	1980- 5-11	0442	51.3	145.170	-41.520	0.0	2.4		ML	2.4	TAU
TAU	1980- 5-12	1744	39.3	146.480	-41.320	0.0	1.5		ML	1.5	TAU
TAU	1980- 5-16	1551	38.7	145.650	-42.830	0.0	1.5		ML	1.5	TAU
TAU	1980- 5-16	2317	17.7	145.830	-42.780	0.0	1.0		ML	1.0	TAU
TAU	1980- 5-22	0613	59.3	146.900	-41.720	0.0	2.2		ML	2.2	TAU
TAU	1980- 5-24	2240	49.3	144.770	-40.920	0.0	1.6		ML	1.6	TAU
TAU	1980- 6- 3	0159	51.9	145.680	-42.630	0.0	2.3		ML	2.3	TAU
TAU	1980- 6- 8	0616	45.6	146.780	-43.430	0.0	1.6		ML	1.6	TAU
TAU	1980- 6-12	0138	26.2	145.980	-43.450	0.0	1.7		ML	1.7	TAU
TAU	1980- 6-26	0347	20.9	145.730	-41.720	0.0	1.8		ML	1.8	TAU
TAU	1980- 6-28	1622	43.6	146.320	-42.920	0.0	1.2		ML	1.2	TAU
TAU	1980- 7- 4	0918	41.5	145.650	-42.170	0.0	1.5		ML	1.5	TAU
TAU	1980- 7-24	0247	48.5	146.920	-43.600	0.0	1.6		ML	1.6	TAU
TAU	1980- 7-26	1752	14.8	145.780	-42.920	0.0	1.0		ML	1.0	TAU
TAU	1980- 7-29	1457	7.3	147.770	-42.150	0.0	1.2		ML	1.2	TAU
TAU	1980- 8-16	2116	35.7	146.080	-43.720	0.0	2.0		ML	2.0	TAU
TAU	1980- 8-18	1614	58.7	145.930	-43.000	0.0	1.2		ML	1.2	TAU
TAU	1980- 8-23	2125	58.4	144.930	-41.150	0.0	2.0		ML	2.0	TAU
TAU	1980- 8-29	0420	17.6	147.350	-43.700	0.0	1.6		ML	1.6	TAU
TAU	1980- 9- 3	1757	50.7	146.720	-43.600	0.0	1.6		ML	1.6	TAU
TAU	1980- 9-15	0403	1.9	145.180	-40.770	0.0	2.6		ML	2.6	TAU
TAU	1980- 9-21	1211	59.9	144.880	-40.750	0.0	2.3		ML	2.3	TAU
TAU	1980-10- 8	0742	24.7	146.130	-43.380	0.0	2.3		ML	2.3	TAU
TAU	1980-10- 8	1432	27.5	145.720	-43.770	0.0	1.6		ML	1.6	TAU
TAU	1980-10-16	2226	35.9	146.180	-42.770	0.0	1.1		ML	1.1	TAU
TAU	1980-10-31	0204	4.7	146.280	-42.700	0.0	1.0		ML	1.0	TAU
TAU	1980-11-10	1422	22.5	146.370	-43.420	0.0	1.2		ML	1.2	TAU
TAU	1980-11-14	0532	48.5	146.750	-43.430	0.0	1.5		ML	1.5	TAU

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time		Long	Lat	Depth	eML	Surface	Local		
TAU	1980-11-16	1627	55.1	145.970	-44.180	0.0	2.4		ML	2.4	TAU
TAU	1980-11-25	0058	13.3	146.820	-42.800	0.0	1.0		ML	1.0	TAU
TAU	1980-12- 8	1210	15.3	144.900	-43.180	0.0	2.0		ML	2.0	TAU
TAU	1980-12- 9	1759	18.6	146.450	-43.700	0.0	2.0		ML	2.0	TAU
TAU	1980-12-10	2229	11.9	146.730	-42.130	0.0	1.1		ML	1.1	TAU
TAU	1980-12-28	0823	50.2	145.450	-42.770	0.0	2.1		ML	2.1	TAU
TAU	1981- 1- 3	1009	31.4	146.200	-43.580	0.0	1.9		ML	1.9	TAU
TAU	1981- 1- 3	1258	40.5	146.650	-42.730	0.0	1.4		ML	1.4	TAU
TAU	1981- 1-10	0833	8.6	147.070	-41.570	0.0	2.2		ML	2.2	TAU
TAU	1981- 1-14	0100	10.7	147.180	-41.500	0.0	1.0		ML	1.0	TAU
TAU	1981- 1-20	1540	13.1	145.080	-42.400	0.0	1.7		ML	1.7	TAU
TAU	1981- 1-27	1635	28.4	144.820	-40.930	0.0	2.0		ML	2.0	TAU
TAU	1981- 2- 4	1724	18.6	146.050	-42.770	0.0	1.0		ML	1.0	TAU
TAU	1981- 2-14	1952	16.5	146.200	-42.800	0.0	1.4		ML	1.4	TAU
TAU	1981- 2-28	0300	0.3	145.180	-40.880	0.0	1.9		ML	1.9	TAU
TAU	1981- 3- 4	0721	17.5	145.720	-41.780	0.0	1.7		ML	1.7	TAU
TAU	1981- 3- 8	2250	11.0	145.530	-42.720	0.0	1.7		ML	1.7	TAU
TAU	1981- 3-10	1039	13.0	146.270	-42.820	0.0	2.1		ML	2.1	TAU
TAU	1981- 3-12	0416	27.2	146.370	-42.950	0.0	1.2		ML	1.2	TAU
TAU	1981- 3-21	0231	1.0	144.900	-40.880	0.0	1.9		ML	1.9	TAU
TAU	1981- 3-29	2356	19.6	145.480	-42.550	0.0	1.2		ML	1.2	TAU
TAU	1981- 3-30	1755	42.8	146.180	-42.700	0.0	1.2		ML	1.2	TAU
TAU	1981- 4- 1	0308	15.7	146.800	-41.930	0.0	1.0		ML	1.0	TAU
TAU	1981- 4- 2	1235	53.6	145.450	-41.070	0.0	2.1		ML	2.1	TAU
TAU	1981- 4- 3	0740	0.8	146.420	-43.670	0.0	1.7		ML	1.7	TAU
TAU	1981- 4- 8	1918	13.9	147.030	-43.780	0.0	1.5		ML	1.5	TAU
TAU	1981- 4-12	2104	37.7	146.170	-43.100	0.0	1.9		ML	1.9	TAU
TAU	1981- 4-26	1944	28.7	146.230	-41.070	0.0	2.7		ML	2.7	TAU
TAU	1981- 4-29	0029	14.8	146.230	-42.720	0.0	1.0		ML	1.0	TAU
TAU	1981- 5- 3	1320	55.7	146.670	-43.010	0.0	1.0		ML	1.0	TAU
TAU	1981- 5-11	0529	50.2	146.270	-42.700	0.0	2.3		ML	2.3	TAU
TAU	1981- 5-11	0611	50.4	146.220	-42.620	0.0	1.0		ML	1.0	TAU
TAU	1981- 5-17	2157	21.1	145.930	-42.850	0.0	1.0		ML	1.0	TAU
TAU	1981- 5-27	1835	7.7	146.070	-43.580	0.0	2.0		ML	2.0	TAU
TAU	1981- 5-28	1257	40.3	145.230	-42.200	0.0	2.1		ML	2.1	TAU
TAU	1981- 6- 6	1822	34.0	147.400	-43.770	0.0	2.4		ML	2.4	TAU
TAU	1981- 6- 9	1310	55.6	146.170	-42.870	0.0	1.0		ML	1.0	TAU
TAU	1981- 6-20	1625	29.6	146.120	-42.680	0.0	1.6		ML	1.6	TAU
TAU	1981- 6-24	0422	35.2	146.580	-43.950	0.0	2.1		ML	2.1	TAU
TAU	1981- 7-11	1321	15.4	146.070	-42.900	0.0	1.0		ML	1.0	TAU
TAU	1981- 7-13	1804	58.1	148.050	-43.370	0.0	1.5		ML	1.5	TAU
TAU	1981- 7-14	1137	10.3	145.100	-40.770	0.0	2.3		ML	2.3	TAU
TAU	1981- 7-22	0221	23.3	145.220	-40.700	0.0	2.5		ML	2.5	TAU
TAU	1981- 8- 3	1652	15.6	147.170	-44.070	0.0	2.0		ML	2.0	TAU
TAU	1981- 8-19	1326	8.6	146.450	-43.150	0.0	2.1		ML	2.1	TAU
TAU	1981- 9-18	1107	52.2	145.120	-42.520	0.0	1.8		ML	1.8	TAU
TAU	1981-10-16	0749	44.5	146.230	-42.820	0.0	1.0		ML	1.0	TAU
TAU	1981-10-19	0732	0.6	146.800	-41.970	0.0	1.4		ML	1.4	TAU

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TAU	1981-10-23	0752 56.1	146.830	-41.800	0.0	1.5		ML 1.5 TAU
TAU	1981-10-29	0634 44.2	146.800	-41.970	0.0	1.3		ML 1.3 TAU
TAU	1981-11- 1	1933 56.9	145.180	-42.930	0.0	1.4		ML 1.4 TAU
TAU	1981-11- 5	0828 42.7	146.080	-42.830	0.0	1.0		ML 1.0 TAU
TAU	1981-11- 8	0420 1.6	146.900	-42.000	0.0	1.0		ML 1.0 TAU
TAU	1981-11-17	0505 1.0	146.980	-43.350	0.0	1.5		ML 1.5 TAU
TAU	1981-11-20	2000 23.7	146.800	-41.270	0.0	1.5		ML 1.5 TAU
TAU	1981-11-23	1948 43.5	146.550	-40.870	0.0	1.2		ML 1.2 TAU
TAU	1981-11-25	0340 12.6	146.780	-43.520	0.0	1.8		ML 1.8 TAU
TAU	1981-11-28	0119 34.3	146.720	-42.420	0.0	1.6		ML 1.6 TAU
TAU	1981-11-29	1207 37.7	146.330	-42.820	0.0	1.0		ML 1.0 TAU
TAU	1981-11-30	0944 53.5	146.270	-42.850	0.0	1.0		ML 1.0 TAU
TAU	1981-11-30	1146 25.1	146.330	-42.820	0.0	1.1		ML 1.1 TAU
TAU	1981-12- 4	0019 57.2	146.100	-42.817	0.0	1.5		ML 1.5 TAU
TAU	1981-12- 4	0108 2.3	146.083	-42.817	0.0	1.0		ML 1.0 TAU
TAU	1981-12- 5	1401 51.5	146.000	-42.683	0.0	1.5		ML 1.5 TAU
TAU	1981-12-11	0339 7.9	145.050	-41.167	0.0	2.0		ML 2.0 TAU
TAU	1981-12-17	0138 9.7	146.967	-43.067	0.0	1.5		ML 1.5 TAU
TAU	1981-12-17	1856 30.5	146.267	-42.700	0.0	1.5		ML 1.5 TAU
TAU	1981-12-24	1416 59.5	146.150	-42.833	0.0	1.2		ML 1.2 TAU
TAU	1981-12-28	1435 58.5	144.767	-41.233	0.0	1.9		ML 1.9 TAU
TAU	1982- 1-10	1439 48.5	145.430	-42.830	0.0	1.3		ML 1.3 TAU
TAU	1982- 1-17	2035 56.0	145.880	-42.850	0.0	1.3		ML 1.3 TAU
TAU	1982- 1-26	1927 42.6	146.800	-43.430	0.0	1.6		ML 1.6 TAU
TAU	1982- 1-31	1225 15.5	145.670	-43.080	0.0	2.0		ML 2.0 TAU
TAU	1982- 2- 4	0750 33.3	145.550	-42.880	0.0	1.7		ML 1.7 TAU
TAU	1982- 2- 6	1720 13.6	145.900	-42.720	0.0	1.9		ML 1.9 TAU
TAU	1982- 2-11	1909 57.6	145.400	-42.730	0.0	1.8		ML 1.8 TAU
TAU	1982- 2-12	2053 10.2	144.950	-42.320	0.0	1.7		ML 1.7 TAU
TAU	1982- 2-14	1944 3.4	146.100	-42.830	0.0	1.0		ML 1.0 TAU
TAU	1982- 2-27	0505 25.8	145.650	-42.730	0.0	1.8		ML 1.8 TAU
TAU	1982- 3-11	1045 53.1	147.820	-42.730	0.0	2.7		ML 2.7 TAU
TAU	1982- 3-20	1647 26.1	146.980	-43.120	0.0	1.0		ML 1.0 TAU
TAU	1982- 3-29	1148 4.6	146.680	-41.820	0.0	1.6		ML 1.6 TAU
TAU	1982- 4-10	1623 54.0	147.320	-42.850	0.0	1.7		ML 1.7 TAU
TAU	1982- 4-18	2034 19.5	147.880	-42.680	0.0	1.6		ML 1.6 TAU
TAU	1982- 4-21	0126 51.5	145.580	-42.670	0.0	1.3		ML 1.3 TAU
TAU	1982- 4-25	1728 51.5	145.700	-41.830	0.0	1.6		ML 1.6 TAU
TAU	1982- 5- 5	0049 31.6	147.850	-42.680	0.0	1.7		ML 1.7 TAU
TAU	1982- 5- 8	0031 52.0	146.130	-43.900	0.0	1.9		ML 1.9 TAU
TAU	1982- 5- 8	1311 9.2	148.180	-43.370	0.0	1.7		ML 1.7 TAU
TAU	1982- 5-27	0020 0.1	146.250	-42.460	0.0	1.0		ML 1.0 TAU
TAU	1982- 6-11	1839 27.9	145.300	-42.730	0.0	1.4		ML 1.4 TAU
TAU	1982- 6-18	1225 57.0	146.420	-42.500	0.0	1.0		ML 1.0 TAU
TAU	1982- 6-18	1228 45.2	146.170	-42.430	0.0	1.0		ML 1.0 TAU
TAU	1982- 6-18	1230 30.1	146.500	-42.580	0.0	1.2		ML 1.2 TAU
TAU	1982- 6-18	1230 43.3	146.130	-42.420	0.0	1.8		ML 1.8 TAU
TAU	1982- 6-18	1231 6.5	146.070	-42.500	0.0	1.4		ML 1.4 TAU

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time		Long	Lat	Depth	eML	Surface	Local		
TAU	1982- 6-18	1235	31.9	146.080	-42.400	0.0	1.0		ML	1.0	TAU
TAU	1982- 6-28	1718	31.8	147.380	-43.380	0.0	1.4		ML	1.4	TAU
TAU	1982- 7-15	1354	34.6	145.580	-42.120	0.0	2.0		ML	2.0	TAU
TAU	1982- 7-27	1552	21.1	146.230	-42.750	0.0	1.6		ML	1.6	TAU
TAU	1982- 8-10	0142	8.0	145.630	-42.820	0.0	1.3		ML	1.3	TAU
BMR	1982- 8-19	1049	0.8	145.191	-40.609	0.0	3.6		ML	3.6	BMR
TAU	1982- 8-21	0628	43.6	147.880	-41.970	0.0	1.8		ML	1.8	TAU
TAU	1982- 9- 4	0437	21.0	147.900	-41.970	0.0	1.4		ML	1.4	TAU
TAU	1982- 9-13	1253	34.4	145.170	-40.700	0.0	2.5		ML	2.5	TAU
TAU	1982- 9-24	1311	34.6	146.670	-44.080	0.0	3.7		ML	3.7	TAU
TAU	1982- 9-25	0725	57.8	146.370	-44.100	0.0	1.9		ML	1.9	TAU
TAU	1982- 9-25	1803	16.7	147.530	-43.730	0.0	1.7		ML	1.7	TAU
TAU	1982-10-17	0349	57.6	146.230	-42.750	0.0	1.1		ML	1.1	TAU
TAU	1982-10-23	1018	1.5	147.880	-42.250	0.0	1.6		ML	1.6	TAU
TAU	1982-10-23	1025	16.6	147.780	-42.270	0.0	1.5		ML	1.5	TAU
TAU	1982-10-23	1905	25.5	145.650	-41.150	0.0	1.4		ML	1.4	TAU
TAU	1982-10-24	1839	44.5	146.230	-42.750	0.0	1.0		ML	1.0	TAU
TAU	1982-10-24	1947	46.1	146.200	-42.680	0.0	1.0		ML	1.0	TAU
TAU	1982-11- 3	0855	12.8	146.950	-41.230	0.0	1.1		ML	1.1	TAU
TAU	1982-11-15	0539	8.9	147.050	-41.380	0.0	1.6		ML	1.6	TAU
TAU	1982-12-16	0617	7.0	145.600	-42.820	0.0	1.6		ML	1.6	TAU
TAU	1982-12-24	2045	57.1	146.660	-43.420	0.0	1.5		ML	1.5	TAU
TAU	1983- 1-12	2342	8.0	145.530	-40.510	0.0	2.0		ML	2.0	TAU
TAU	1983- 1-21	1715	1.8	145.080	-41.150	0.0	2.5		ML	2.5	TAU
TAU	1983- 1-24	0138	47.8	144.820	-40.830	14.0	2.6		ML	2.6	TAU
TAU	1983- 1-29	0153	46.1	146.330	-42.900	0.0	1.5		ML	1.5	TAU
TAU	1983- 2- 7	2358	50.5	147.880	-41.800	0.0	2.3		ML	2.3	TAU
TAU	1983- 2-18	2040	43.4	146.580	-42.530	0.0	1.0		ML	1.0	TAU
TAU	1983- 3- 8	2324	12.9	145.410	-43.300	0.0	2.5		ML	2.5	TAU
TAU	1983- 3-24	1156	20.3	145.500	-42.850	0.0	1.8		ML	1.8	TAU
TAU	1983- 3-24	1520	18.9	145.330	-42.180	0.0	1.9		ML	1.9	TAU
TAU	1983- 3-29	0410	5.2	146.550	-43.150	0.0	1.5		ML	1.5	TAU
TAU	1983- 4- 2	1022	49.7	147.080	-42.250	0.0	1.3		ML	1.3	TAU
TAU	1983- 4- 9	0143	39.1	145.550	-42.800	0.0	1.7		ML	1.7	TAU
TAU	1983- 4- 9	0902	4.2	144.530	-41.150	0.0	2.7		ML	2.7	TAU
TAU	1983- 4- 9	1213	22.3	146.560	-43.750	0.0	1.9		ML	1.9	TAU
TAU	1983- 4-29	1534	53.9	145.630	-42.960	0.0	1.5		ML	1.5	TAU
TAU	1983- 5- 5	1015	46.7	145.930	-41.430	0.0	1.6		ML	1.6	TAU
TAU	1983- 5- 6	1621	3.4	145.580	-43.330	0.0	1.6		ML	1.6	TAU
TAU	1983- 5- 7	1250	8.3	145.850	-43.780	0.0	1.9		ML	1.9	TAU
TAU	1983- 5- 9	1659	56.0	144.830	-40.550	0.0	2.1		ML	2.1	TAU
TAU	1983- 5-10	1311	6.9	146.700	-42.150	0.0	1.8		ML	1.8	TAU
TAU	1983- 5-20	1013	5.2	147.930	-41.750	0.0	1.4		ML	1.4	TAU
TAU	1983- 5-21	2115	24.5	146.680	-43.750	0.0	1.7		ML	1.7	TAU
TAU	1983- 5-26	1515	33.1	147.630	-43.870	0.0	1.7		ML	1.7	TAU
TAU	1983- 5-28	0529	27.8	145.620	-42.080	0.0	2.1		ML	2.1	TAU
TAU	1983- 7-23	2005	40.0	147.270	-42.730	0.0	1.0		ML	1.0	TAU
TAU	1983- 7-26	0508	14.2	147.000	-41.780	0.0	1.0		ML	1.0	TAU

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TAU	1983- 7-27	1650 48.1	147.230	-42.250	0.0	1.8		ML 1.8 TAU
TAU	1983- 8- 7	0809 47.0	145.900	-43.020	0.0	1.7		ML 1.7 TAU
TAU	1983- 8-16	1749 53.3	145.980	-42.830	0.0	1.2		ML 1.2 TAU
TAU	1983- 8-20	1609 33.8	146.170	-43.420	0.0	1.5		ML 1.5 TAU
TAU	1983- 8-29	1731 41.8	147.980	-42.770	0.0	1.4		ML 1.4 TAU
TAU	1983- 9- 6	1126 34.2	146.520	-42.620	0.0	1.4		ML 1.4 TAU
TAU	1983- 9- 8	0116 28.2	146.330	-42.800	0.0	1.0		ML 1.0 TAU
TAU	1983- 9- 9	0821 13.4	146.370	-42.930	0.0	1.8		ML 1.8 TAU
TAU	1983- 9- 9	0824 42.3	146.370	-42.900	0.0	1.3		ML 1.3 TAU
TAU	1983- 9-10	0140 58.6	145.670	-42.830	0.0	1.9		ML 1.9 TAU
TAU	1983- 9-26	1149 17.7	146.080	-42.770	0.0	1.0		ML 1.0 TAU
TAU	1983- 9-29	0306 23.2	144.730	-42.250	0.0	2.5		ML 2.5 TAU
TAU	1983-10- 2	1352 14.6	146.130	-43.480	0.0	2.0		ML 2.0 TAU
TAU	1983-10- 6	1432 7.1	146.230	-42.650	0.0	2.1		ML 2.1 TAU
TAU	1983-10-10	0834 1.9	147.570	-43.520	0.0	2.2		ML 2.2 TAU
TAU	1983-10-10	2331 37.9	147.300	-43.530	0.0	1.9		ML 1.9 TAU
TAU	1983-10-22	0236 55.3	146.230	-42.670	0.0	1.5		ML 1.5 TAU
TAU	1983-10-26	0854 53.1	147.880	-42.130	0.0	1.9		ML 1.9 TAU
TAU	1983-11- 8	0336 30.2	146.150	-42.930	0.0	1.0		ML 1.0 TAU
TAU	1983-11- 9	1923 26.8	145.380	-40.780	0.0	2.3		ML 2.3 TAU
TAU	1983-11-20	1105 18.1	148.300	-43.470	0.0	1.6		ML 1.6 TAU
TAU	1983-11-27	2259 55.5	145.320	-42.550	0.0	1.9		ML 1.9 TAU
TAU	1983-12-14	1332 14.7	146.230	-42.730	0.0	1.0		ML 1.0 TAU
TAU	1984- 1- 9	1849 55.6	146.500	-43.280	0.0	1.4		ML 1.4 TAU
TAU	1984- 1-13	0813 3.8	145.080	-41.780	0.0	2.1		ML 2.1 TAU
TAU	1984- 1-18	0319 13.0	146.170	-43.250	0.0	2.9		ML 2.9 TAU
TAU	1984- 1-18	1339 8.8	145.280	-41.820	0.0	1.4		ML 1.4 TAU
TAU	1984- 1-22	0244 18.8	146.230	-42.650	0.0	1.1		ML 1.1 TAU
TAU	1984- 2- 4	1741 17.3	147.270	-42.280	0.0	2.5		ML 2.5 TAU
TAU	1984- 2- 7	2305 6.8	147.330	-43.000	0.0	1.2		ML 1.2 TAU
TAU	1984- 2-22	0901 53.0	148.020	-41.950	0.0	1.6		ML 1.6 TAU
TAU	1984- 3- 4	1950 25.0	145.970	-42.870	0.0	1.0		ML 1.0 TAU
TAU	1984- 3- 9	1851 22.8	145.500	-42.780	0.0	1.9		ML 1.9 TAU
TAU	1984- 3-15	0619 27.8	146.680	-43.180	0.0	1.4		ML 1.4 TAU
TAU	1984- 3-22	0856 26.0	145.620	-42.170	0.0	1.2		ML 1.2 TAU
TAU	1984- 3-22	1107 47.1	146.130	-42.770	0.0	1.2		ML 1.2 TAU
TAU	1984- 3-28	0656 11.1	146.200	-42.780	0.0	1.0		ML 1.0 TAU
TAU	1984- 4- 6	0927 20.6	146.320	-42.820	0.0	1.0		ML 1.0 TAU
TAU	1984- 5- 1	1355 47.8	146.730	-41.650	0.0	1.7		ML 1.7 TAU
TAU	1984- 5-25	1313 40.9	145.720	-41.600	0.0	1.3		ML 1.3 TAU
TAU	1984- 7-13	2118 10.3	145.120	-42.100	0.0	1.9		ML 1.9 TAU
TAU	1984- 8-10	2207 20.9	147.180	-42.370	0.0	1.1		ML 1.1 TAU
TAU	1984- 8-20	0323 43.8	145.450	-40.850	0.0	2.5		ML 2.5 TAU
TAU	1984- 8-25	0617 38.8	145.920	-42.770	0.0	1.1		ML 1.1 TAU
TAU	1984- 8-27	0618 22.4	146.350	-42.930	0.0	2.5		ML 2.5 TAU
TAU	1984- 9- 6	2201 18.0	147.120	-42.070	0.0	1.6		ML 1.6 TAU
TAU	1984- 9-23	1518 3.8	145.930	-41.430	0.0	2.2		ML 2.2 TAU
TAU	1984-10- 1	1354 57.0	145.530	-41.620	0.0	1.4		ML 1.4 TAU

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time	Long	Lat	Depth	eML	Surface	Local
TAU	1984-10- 9	0016 31.6	146.550	-43.170	0.0	1.3		ML 1.3 TAU
TAU	1984-10-10	0353 34.2	146.420	-42.880	0.0	1.6		ML 1.6 TAU
TAU	1984-10-18	1608 22.5	147.230	-43.970	0.0	1.8		ML 1.8 TAU
TAU	1984-10-19	0847 34.4	146.220	-42.700	0.0	1.2		ML 1.2 TAU
PIT	1984-10-20	0609 9.6	145.918	-43.159	12.0	1.6		ML 1.6 PIT
TAU	1984-11- 8	1659 1.7	146.220	-43.470	0.0	1.2		ML 1.2 TAU
TAU	1984-11-19	0712 52.1	146.550	-42.550	0.0	1.1		ML 1.1 TAU
TAU	1984-12- 8	0541 33.4	144.930	-41.250	0.0	2.1		ML 2.1 TAU
TAU	1984-12-10	0622 41.7	145.520	-42.130	0.0	1.8		ML 1.8 TAU
TAU	1984-12-26	0505 19.7	147.170	-43.020	0.0	1.0		ML 1.0 TAU
TAU	1984-12-26	0507 15.3	147.620	-42.930	0.0	1.7		ML 1.7 TAU
TAU	1984-12-27	0321 37.1	148.130	-43.300	0.0	1.4		ML 1.4 TAU
TASU	1985- 1-18	0926 9.0	147.320	-42.500	0.0	1.0		ML 1.0 TAU
TASU	1985- 1-21	0814 15.0	145.720	-41.770	0.0	1.7		ML 1.7 TAU
TASU	1985- 2-11	2354 26.0	146.330	-42.830	0.0	1.1		ML 1.1 TAU
TASU	1985- 3- 7	1749 24.1	146.470	-43.320	0.0	1.8		ML 1.8 TAU
TASU	1985- 3-25	2327 21.6	145.150	-41.150	0.0	2.6		ML 2.6 TAU
TASU	1985- 4- 9	0912 34.6	146.880	-41.770	0.0	1.0		ML 1.0 TAU
TASU	1985- 4-22	0409 56.4	146.420	-43.730	0.0	1.7		ML 1.7 TAU
TASU	1985- 4-26	1431 44.5	145.050	-41.060	0.0	1.9		ML 1.9 TAU
TASU	1985- 6-12	1844 34.2	147.400	-41.800	0.0	1.3		ML 1.3 TAU
TASU	1985- 7- 1	0200 29.0	146.670	-41.650	0.0	2.0		ML 2.0 TAU
TASU	1985- 7-14	1832 41.3	147.430	-43.820	0.0	2.6		ML 2.6 TAU
TASU	1985- 8-30	0650 58.6	146.820	-43.550	0.0	2.3		ML 2.3 TAU
TASU	1985-11-12	0730 4.9	147.830	-43.170	0.0	1.9		ML 1.9 TAU
TASU	1985-11-19	0052 46.4	147.780	-42.470	0.0	1.7		ML 1.7 TAU
TASU	1985-12-26	2032 39.7	147.060	-43.630	0.0	1.8		ML 1.8 TAU
TAU	1986- 1-19	0736 48.4	144.850	-41.030	0.0	2.0		ML 2.0 TAU
TAU	1986- 1-27	1625 2.1	146.250	-43.050	0.0	1.8		ML 1.8 TAU
TAU	1986- 2-26	2222 0.1	145.550	-42.350	0.0			NL 2.2 TAU
TAU	1986- 3-15	1447 39.3	146.270	-42.620	0.0	1.2		ML 1.2 TAU
BMR	1986- 3-16	0153 10.5	144.632	-41.451	18.0	4.1		ML 4.1 BMR
TAU	1986- 3-20	1949 4.5	145.280	-42.100	0.0	2.1		ML 2.1 TAU
TAU	1986- 3-22	1506 4.4	144.830	-41.570	0.0	1.7		ML 1.7 TAU
TAU	1986- 3-22	1512 1.6	144.850	-41.330	0.0	2.0		ML 2.0 TAU
TAU	1986- 3-22	1521 45.4	145.070	-41.380	0.0	1.7		ML 1.7 TAU
TAU	1986- 3-23	1544 47.4	145.850	-42.900	0.0	1.3		ML 1.3 TAU
TAU	1986- 4- 6	2207 42.4	146.500	-43.230	0.0	2.0		ML 2.0 TAU
TAU	1986- 4-23	0600 17.9	145.570	-41.870	0.0	1.9		ML 1.9 TAU
TAU	1986- 5- 6	2106 39.0	146.200	-41.580	0.0	1.6		ML 1.6 TAU
TAU	1986- 5-13	1047 11.1	145.420	-42.080	0.0	1.5		ML 1.5 TAU
TAU	1986- 5-14	0954 9.9	146.550	-42.870	0.0	1.2		ML 1.2 TAU
TAU	1986- 5-29	0336 14.1	146.300	-43.420	0.0	2.4		ML 2.4 TAU
TAU	1986- 6-15	1113 2.7	147.620	-42.920	0.0	1.0		ML 1.0 TAU
TAU	1986- 6-21	1649 14.1	146.570	-43.430	0.0	2.0		ML 2.0 TAU
TAU	1986- 6-26	0049 30.9	145.550	-42.200	0.0	2.4		ML 2.4 TAU
TAU	1986- 7- 9	1648 3.5	145.280	-41.220	0.0	2.0		ML 2.0 TAU
TAU	1986- 7-12	0756 35.1	146.580	-41.920	0.0	2.4		ML 2.4 TAU

Catalogue BMR, format BMR, from start to 1987-12-23
Select only the preferred location for each earthquake
Select events with:
Longitude greater than or equal to 144.50 and less than or equal to 148.50
Latitude greater than or equal to -44.50 and less than or equal to -40.50

Srce	UT Date	Time		Long	Lat	Depth	eML	Surface	Local		
TAU	1986- 7-19	2017	50.5	146.870	-41.880	0.0	1.4		ML	1.4	TAU
TAU	1986- 7-22	2305	18.3	145.300	-41.330	0.0	1.9		ML	1.9	TAU
TAU	1986- 7-23	0020	47.1	145.180	-41.270	0.0	2.3		ML	2.3	TAU
TAU	1986- 8- 6	0212	18.4	146.820	-42.970	0.0	1.5		ML	1.5	TAU
TAU	1986- 8- 9	2035	41.6	145.930	-42.450	0.0	1.7		ML	1.7	TAU
TAU	1986- 9-15	1330	23.5	145.420	-42.000	0.0	1.6		ML	1.6	TAU
TAU	1986- 9-28	0259	31.1	146.370	-43.180	0.0	1.5		ML	1.5	TAU
TAU	1986- 9-29	1136	40.0	146.770	-42.450	0.0	1.3		ML	1.3	TAU
TAU	1986-10- 9	0526	14.7	148.480	-43.400	0.0	1.6		ML	1.6	TAU
TAU	1986-11-10	0618	0.0	147.840	-42.800	0.0	1.0		ML	1.0	TAU
TAU	1986-11-11	0202	0.0	147.840	-42.800	0.0	2.1		ML	2.1	TAU
TAU	1986-11-11	0207	0.0	147.840	-42.800	0.0	1.6		ML	1.6	TAU
TAU	1986-11-12	0427	0.0	147.840	-42.800	0.0	2.0		ML	2.0	TAU
TAU	1986-11-12	0742	0.0	147.840	-42.800	0.0	2.0		ML	2.0	TAU
TAU	1986-11-12	1229	0.0	147.840	-42.800	0.0	1.7		ML	1.7	TAU
TAU	1986-11-12	1423	0.0	147.840	-42.800	0.0	1.6		ML	1.6	TAU
TAU	1986-12- 6	1537	41.2	147.800	-42.050	0.0	1.7		ML	1.7	TAU
TAU	1986-12-18	2141	15.3	145.830	-42.500	0.0	2.6		ML	2.6	TAU
TAU	1986-12-26	0442	18.2	144.530	-41.530	0.0	2.7		ML	2.7	TAU

739 events listed

APPENDIX 6

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CSIRO Marine Laboratories

REPORT 88-HC1

HYDROCARBONS IN ORDOVICIAN LIMESTONES

FROM QUEENSTOWN AND LUNE RIVER, TASMANIA

PREPARED BY: J. K. VOLKMAN
CSIRO DIVISION OF OCEANOGRAPHY.

FEBRUARY 22nd., 1988

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CSIRO

775190

MARINE LABORATORIES

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Division of Oceanography

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HYDROCARBONS IN ORDOVICIAN LIMESTONES FROM QUEENSTOWN AND LUNE RIVER, TASMANIA

CLIENT: Conga Oil Pty. Ltd.
84 Wells Parade
Blackmans Bay
Tasmania

DATE OF REPORT: February 22nd., 1988

CONTENTS

PAGE

SAMPLES

Three samples of Ordovician limestones were supplied by Mr. Malcolm Bendall of Conga Oil for analysis of hydrocarbons. These data were to be compared with the distributions of hydrocarbons found in suspected seeps from Bruny Island (Volkman, 1987) and hydrocarbons in sediments from the D'Entrecasteaux Channel.

Two of the samples were obtained from an outcrop near Queenstown, Tasmania and provided as several kilograms of crushed material in plastic bags. Sample Q1 was representative of the bulk limestone and was light grey in colour. Q2 was a sample of limestone containing brown tars. The third sample was obtained from an outcrop at Lune River near Ida Bay and labelled IB.

METHODS AND RESULTS

(a) Total extract

Approximately one kilogram of each sample was extracted several times with chloroform-methanol to obtain a total extract. The efficiency of the extraction was enhanced by the use of an ultrasonic probe. A portion of the extract was analysed by Iatroscan thin-layer chromatography-flame ionisation detection (Volkman et al., 1986) from which the concentration of total hydrocarbons was calculated using appropriate calibration factors. Note that these amounts include all hydrocarbons (aliphatic and aromatic).

TLC-FID chromatograms are shown in Figure 1 and concentrations are given in Table 1. These values are calculated relative to the dry weight of sediment and have a possible error of ± 15%.

Hydrocarbons made up a significant part of the extractable organic matter in each of the three samples, although the total amount of hydrocarbons was quite low at about 1 ppm. Such values are typical of many limestones with low organic carbon contents. There was no evidence for appreciable amounts of oxygenated lipids, such as free fatty acids or sterols, which are commonly found in immature sediments.

TABLE 1. CONCENTRATIONS OF HYDROCARBONS IN ORDOVICIAN LIMESTONES

SAMPLE	LOCATION	CONCENTRATION (ug/g dry wt.)
IB	Lune River, Ida Bay	2.9
Q1	Queenstown	0.76
Q2	Queenstown	1.2

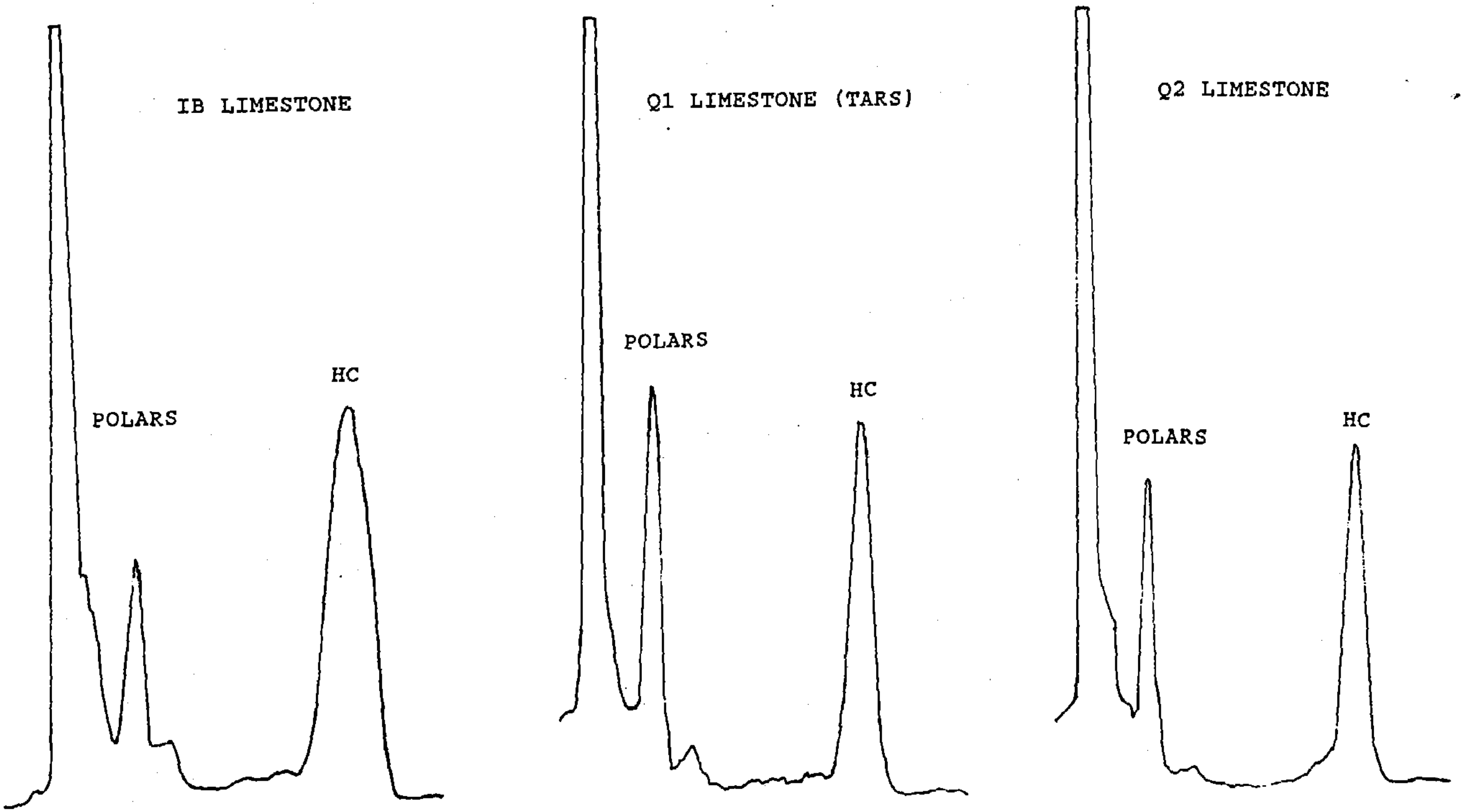

Figure 1. Iatroscan thin layer chromatography-flame ionisation detection (TLC-FID) chromatograms of organic matter in Ordovician limestones. POLARS-polar lipids; HC-hydrocarbons. [redacted]Sol[redacted]t s[redacted]em[redacted]exa[redacted]di[redacted]yl [redacted]ther [redacted]:6.

(b) Hydrocarbons

Total hydrocarbons were separated by applying an aliquot of the total extract to a column of silica gel and eluting with hexane-toluene mixtures. These were then analysed by capillary gas chromatography on a 50 meter non-polar methyl silicone fused silica capillary column. Gas chromatograms of the total hydrocarbons (aliphatics plus aromatics) are shown in Figures 2-4. Ratios of selected components are shown in Table 2.

Major constituents in each of the three samples were straight-chain alkanes ranging in chain-length from C_{15} to at least C_{35}. There was a slight predominance of odd-carbon chain lengths in the C_{21}-C_{35} range in the two samples from Queeenstown. Such distributions are typical of the plant wax hydrocarbons that have been modified by thermal degradation. No such predominance was seen in the hydrocarbons from the Ida Bay sample. The predominance of short-chain ($<C_{20}$) n-alkanes, and the lack of an odd or even preference, is consistent with hydrocarbons that have been generated by heating.

The chromatograms from the two Queenstown samples were very similar and differed only in the relative abundances of a few compounds. The main compound in Q2 was n-C_{18}, whereas in Q1 it was n-C_{17}. This difference could be due to losses of the more volatile hydrocarbons during workup (although precautions to minimise this were taken) or due to weathering of the outcrop sample. It is highly likely that the unweathered sediments would contain appreciable amounts of hydrocarbons with chain-lengths $<C_{15}$.

The distribution of hydrocarbons in the Ida Bay sample was also broadly similar to the other two, but n-alkanes comprised a greater proportion of the total hydrocarbons (compare n-C_{17}/pristane ratios, Table 2).

Each of the three samples showed a significant "unresolved complex mixture" (UCM or hump) which is typical of the hydrocarbons found in crude oils or thermally mature sediments. This UCM consists of a very complex mixture of branched and cyclic alkanes that cannot be resolved into individual components, even by the high resolution capillary columns used in this study.

Suites of simple branched and cyclic alkanes were observed in each sample as multiplets of peaks eluting between each pair of n-alkanes. GC-MS data showed these to be mainly alkylcyclohexanes and alkylated methyl cyclohexanes similar to those found in other Ordovician samples (Hoffmann et al., 1987).

The isoprenoid alkanes pristane and phytane were conspicuous in each of the three chromatograms. The ratio of these two compounds is often used as an indicator of source and depositional environment but one needs to exercise caution in such interpretations (Volkman and Maxwell, 1986). Since there are possible problems with co-elution with other compounds, this ratio was calculated from the more-specific GC-MS data (Table 2).

IB LIMESTONE

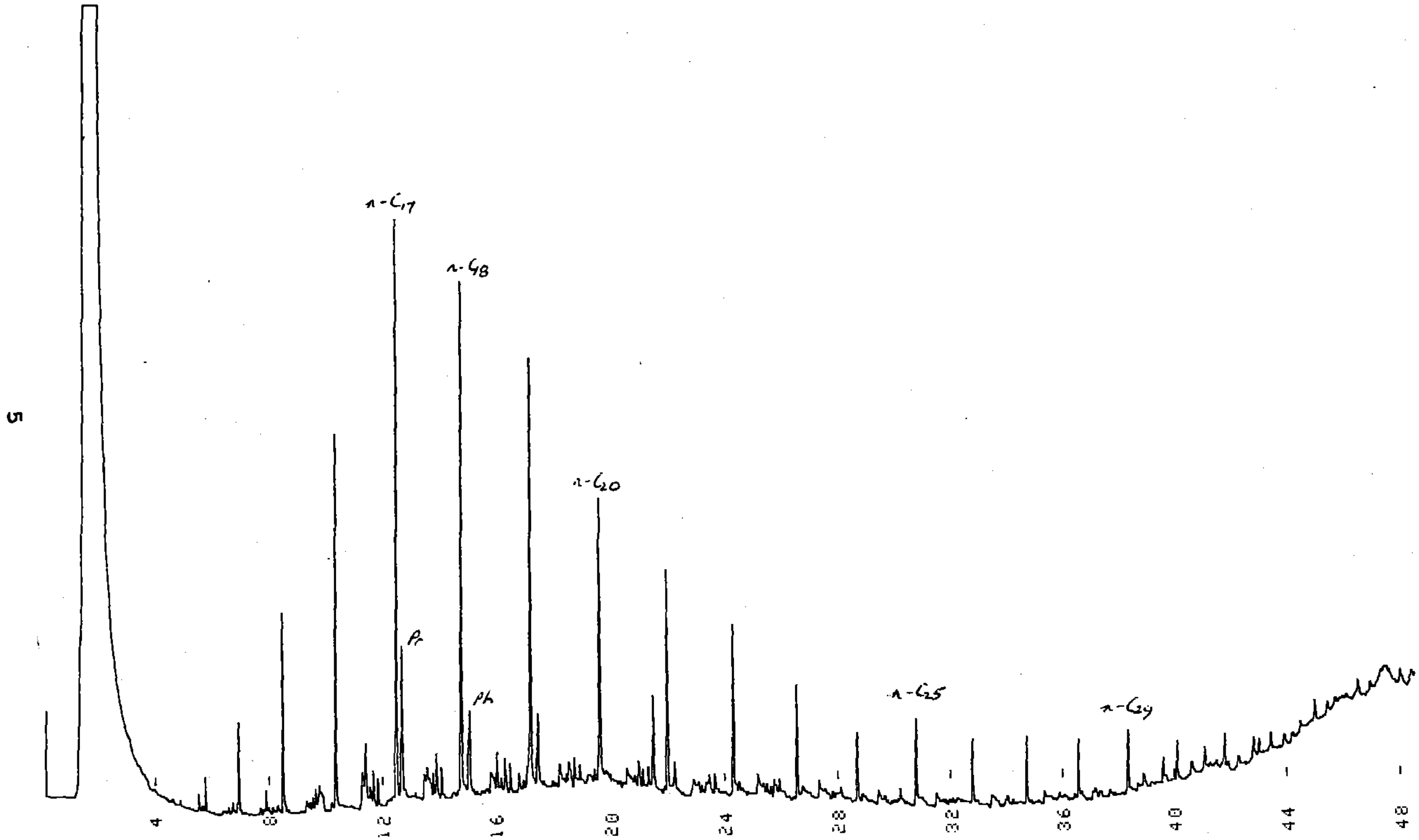

Figure 2. Capillary gas chromatogram of aliphatic hydrocarbons in IB limestone.

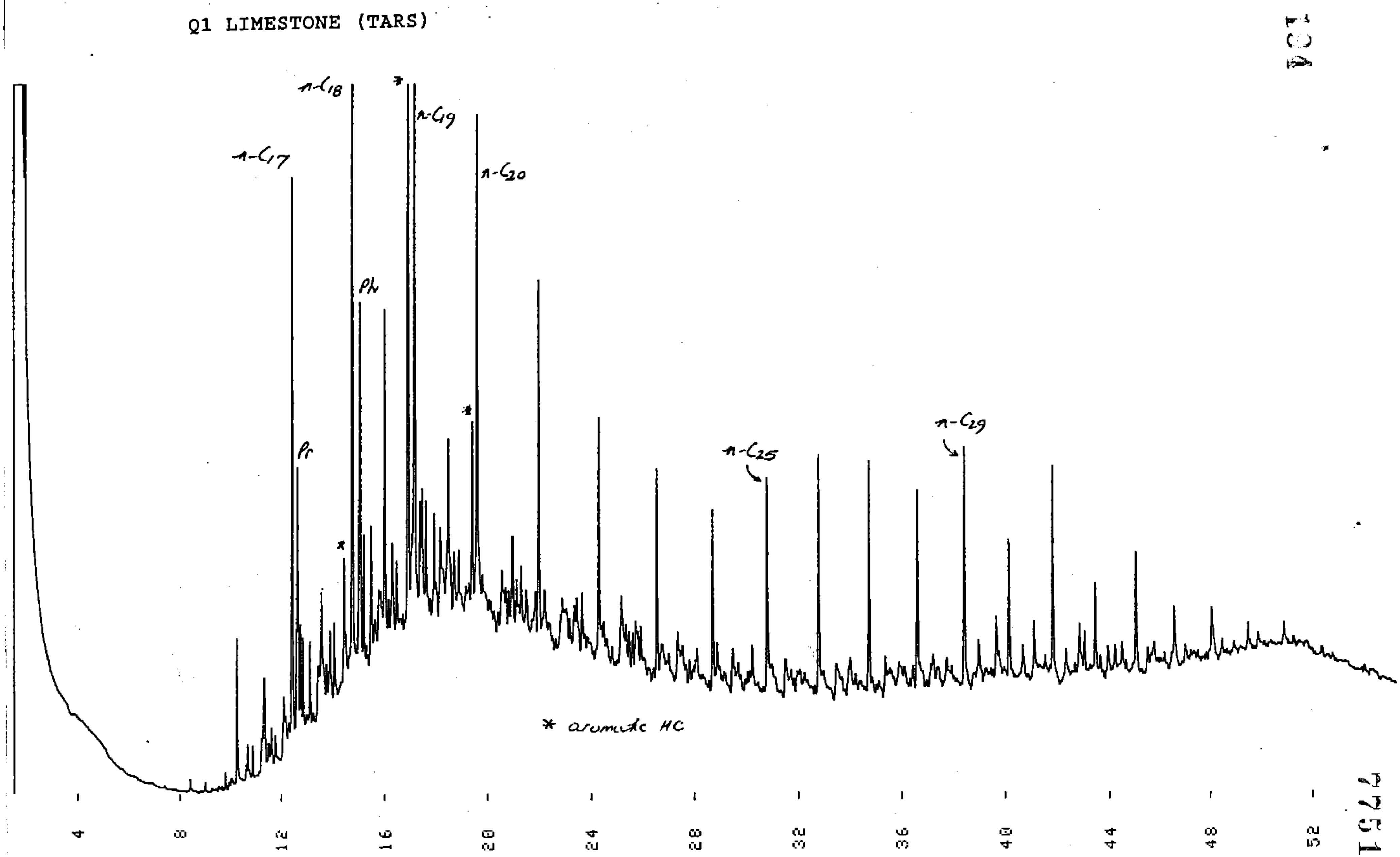

Figure 3. Capillary gas chromatogram of aliphatic hydrocarbons in Q1 limestone. * indicates alkyl benzenes not separated from aliphatic hydrocarbons by silica gel chromatography.

Q2 LIMESTONE

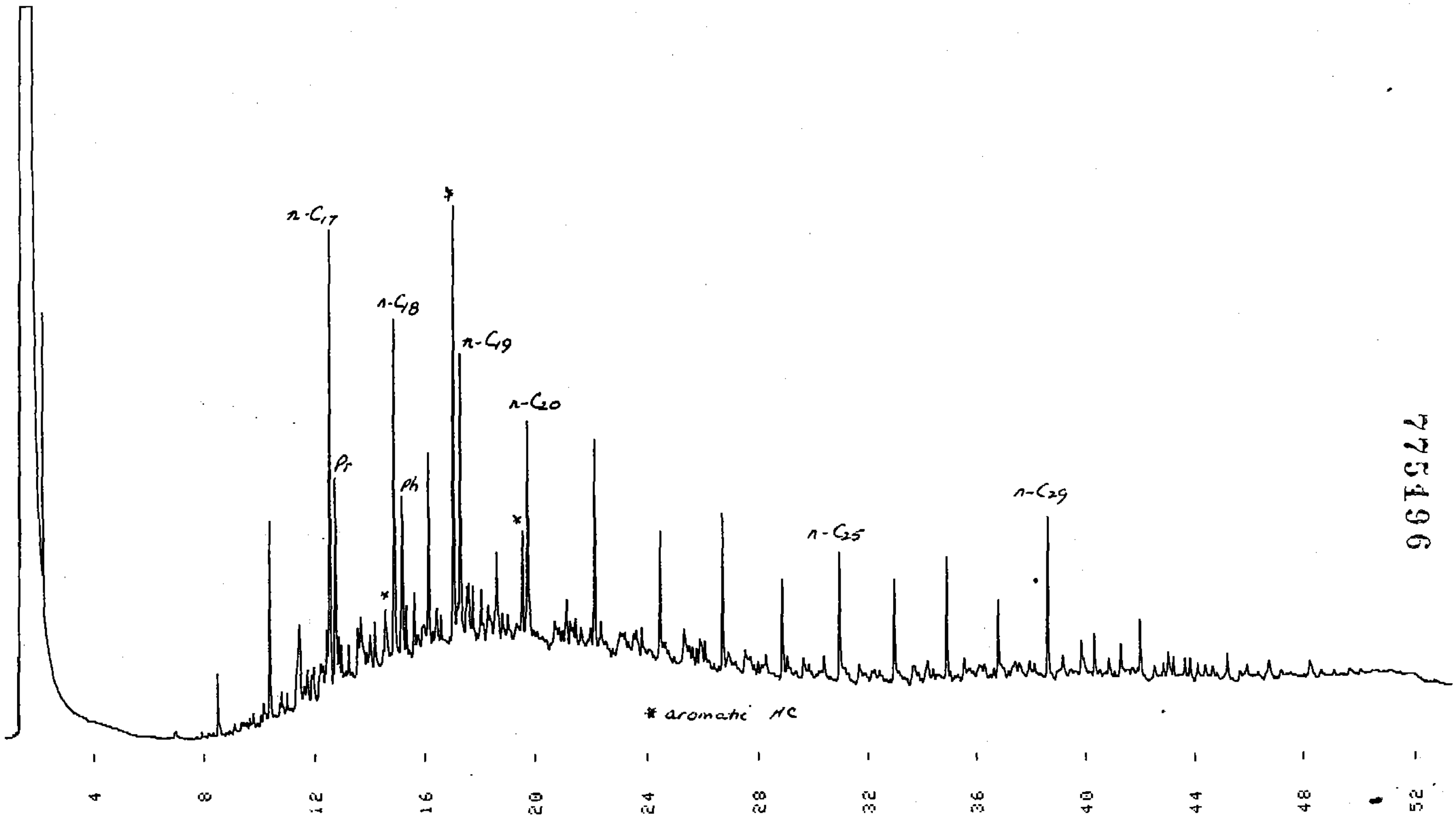

Figure 4. Capillary gas chromatogram of aliphatic hydrocarbons in Q2 limestone. * indicates alkyl benzenes not separated from aliphatic hydrocarbons by silica gel chromatography.

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(c) Biomarkers

Each of the aliphatic hydrocarbon fractions was analysed by capillary gas chromatography-mass spectrometry to obtain full scan electon-impact mass spectra of major components. These data were useful in identifying n-alkanes, isoprenoids and alkyl cyclohexanes. Several aromatic compounds were also identified in the Queenstown samples from these data as indicated on Figures 3 and 4. Aromatic compounds usually occur in the second fraction from the silica gel column but presumably eluted earlier with the aliphatic compounds due to their low molecular weight.

Distributions of polycyclic biomarkers typical of crude oils were determined using the selected ion monitoring facility of the mass spectrometer. Data for ions m/z 217 and 218 (steranes), m/z 259 (diasteranes), m/z 191 (hopanes), m/z 177 and 205 (certain hopanes), m/z 113 and 183 (acyclic isoprenoids) and various molecular ions were acquired. Representative mass fragmentograms are shown in Figures 5-18. Quantitative data for selected biomarker parameters are shown in Table 2.

It was not necessary to separate branched/cyclic alkanes from straight-chain compounds using molecular sieves for this study, although this procedure would be useful if a more detailed study of minor branched compounds was contemplated. These analyses are stored on computer disk should other presentations of the data be required.

The three samples were found to contain distributions of hydrocarbon biomarkers that are typical of a thermally mature sediment. Biogenic hydrocarbons were at most trace constituents.

The sterane and hopane data suggest that the limestones have been heated to an equivalent vitrinite reflectance of about 0.6. A precise estimate is not possible but it is clear that the limestones are within the early section of the oil window.

TABLE 2

SELECTED BIOMARKER PARAMETERS FROM GC-MS ANALYSIS

SAMPLES: Ordovician limestones from Queenstown and Lune River supplied by Mr. Malcolm Bendall.

MATURITY PARAMETERS	IB	Q1	Q2
1. C_{27} hopanes: T_s/T_m	0.74	0.79	0.78
2. C_{30} hopane/C_{30} moretane	11.6	10.6	8.1
3. C_{31} 22S hopane/(C_{31} 22R + 22S hopanes) X 100	59	56	57
4. C_{32} 22S hopane/(C_{32} 22R + 22S hopanes) X 100	60	60	60
5. C_{29} $\alpha\alpha\alpha$-steranes: 20S/20R	0.99	1.02	1.09
6. C_{29} 20R steranes: $\alpha\beta\beta/\alpha\alpha\alpha$	1.07	1.13	1.12
SOURCE PARAMETERS			
7. C_{27}/C_{29} steranes	1.03	1.16	1.32
8. C_{27}/C_{29} diasteranes	1.00	1.09	1.23
9. Pristane/phytane	1.6	1.4	1.9
10. Pristane/n-C_{17}	0.26	0.47	0.46
11. C_{17} alkylcyclohexane/n-C_{17}	0.07	0.13	0.10

Parameters 1-4 calculated from m/z 191 mass fragmentograms
Parameters 5-7 calculated from m/z 217 mass fragmentograms
Parameter 8 calculated from m/z 259 mass fragmentograms
Parameter 9 calculated from m/z 113 mass fragmentograms.
Parameter 10 calculated from capillary gas chromatogram
Parameter 11 calculated from total ion chromatogram

(i) Acyclic isoprenoid alkanes.

Pristane and phytane were the major branched alkanes in the three samples. The ratio of pristane to phytane was calculated from m/z 113 mass fragmentograms obtained from SIM analysis of the total aliphatic hydrocarbons. Mass fragmentograms are shown in Figure 5.

The three samples had values of 1.4, 1.6 and 1.9 (Table 2). A range of values from 0.2 to 2.1 were obtained for the suspected oil seeps from Bruny Island (Volkman, 1987; note that the value for B7 should be 2.1 not 1.1 as shown in Table 1 of this reference). Values greater than one are usually found in sediments from environments which are predominantly oxic.

(ii) Alkyl cyclohexanes

A series of alkyl cyclohexanes was detected in each of the samples by monitoring the ion m/z 83 which is the base peak in the mass spectra of these compounds. These compounds were less than one-tenth the abundance of n-alkanes (compare C_{17} alkylcyclohexane/n-C_{17} ratios in Table 2). Shorter-chain homologues predominated in each case and the distributions closely resembled those of the n-alkanes (Figure 6) except in the higher molecular weight region. Similar distributions have been observed in other Ordovician samples (Hoffmann et al., 1987), although it must be noted that alkyl cyclohexanes are also found in many other sediments.

A series of alkylated methyl cyclohexanes was also detected in each sample by monitoring the ion m/z 97, but detailed identifications could not be attempted due to a lack of standards.

ISOPRENOID ALKANES

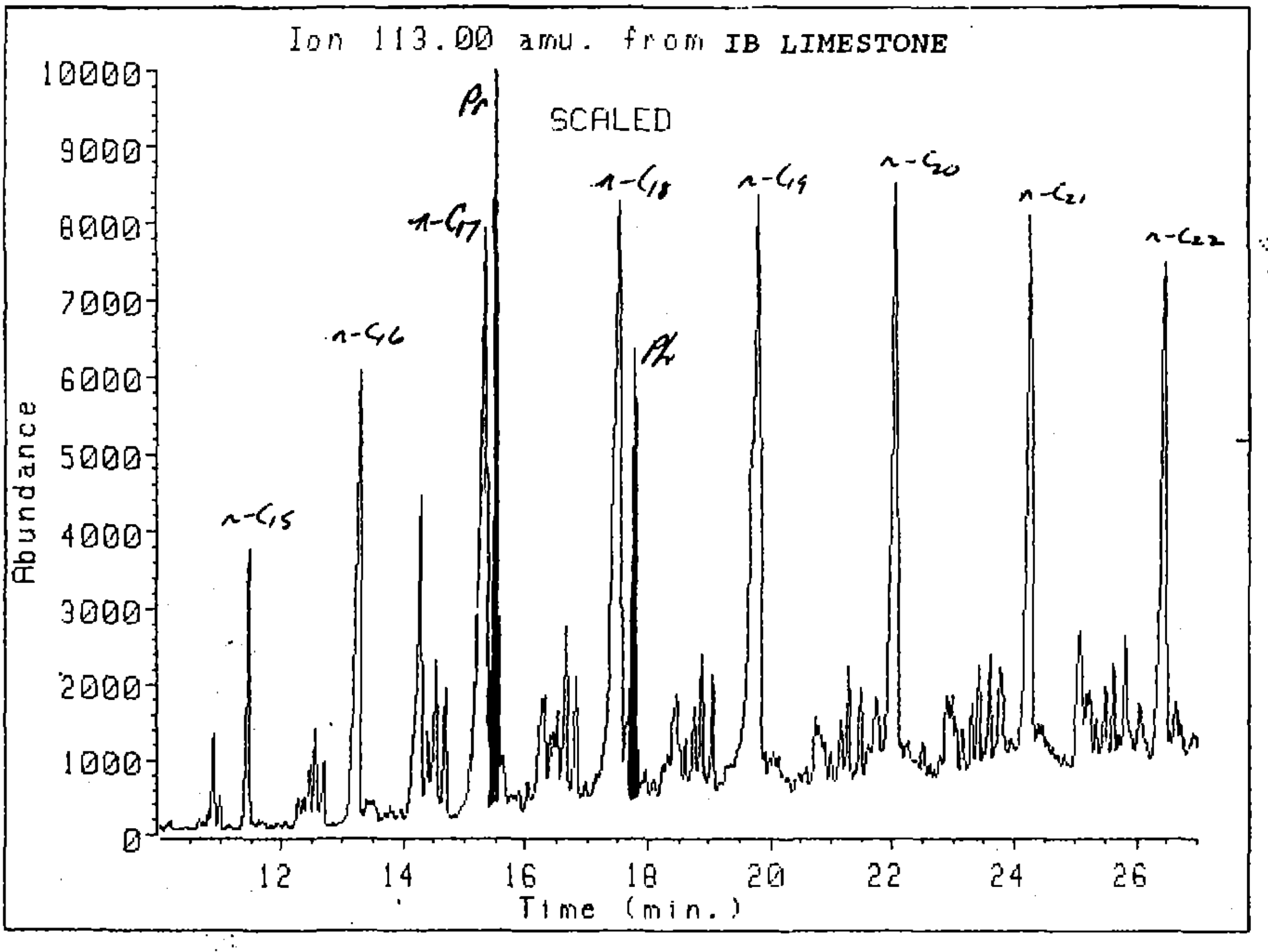
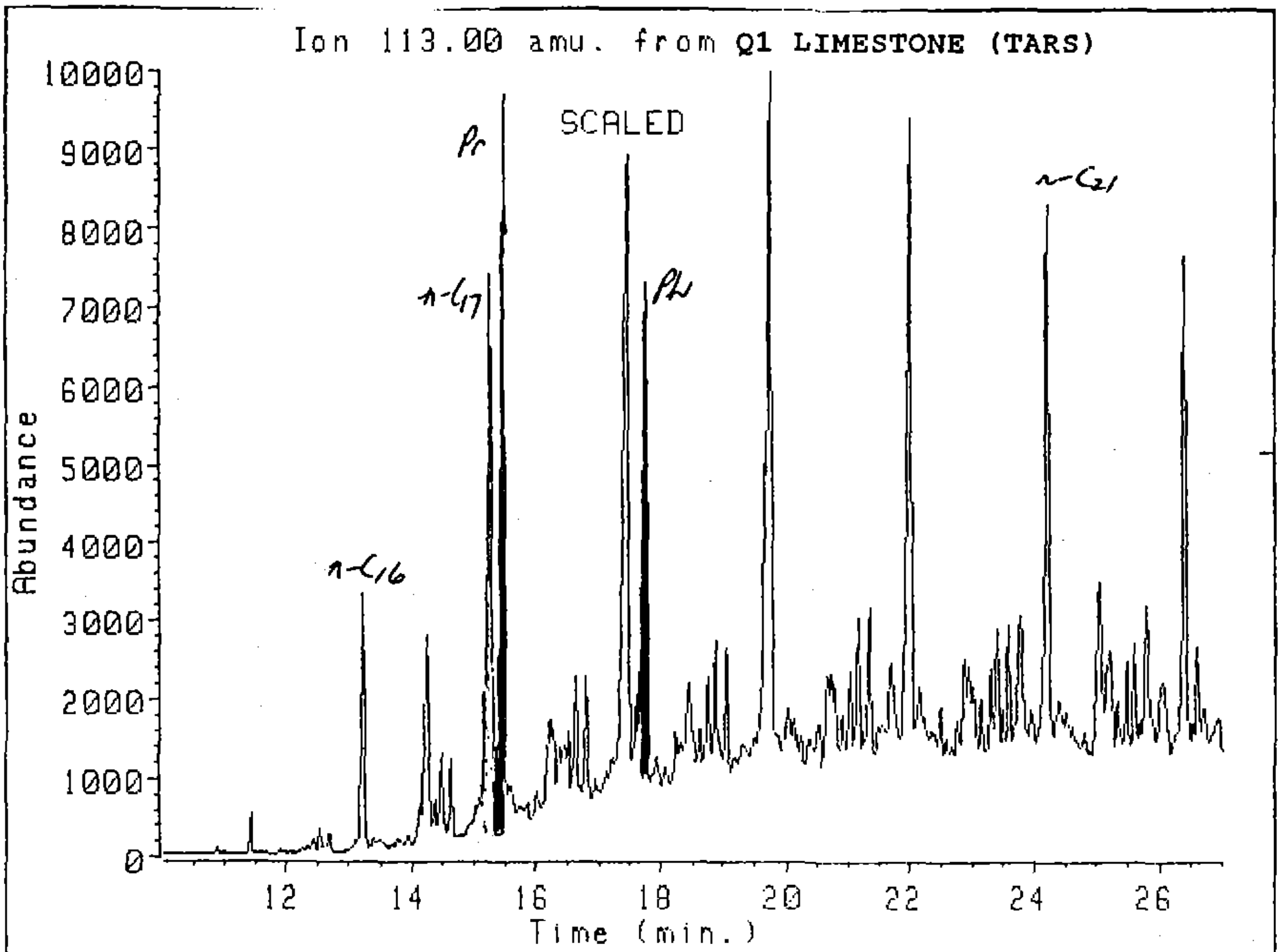


Figure 5a. Mass fragmentogram for m/z 113 showing distributions of isoprenoid alkanes in Ida Bay limestone. Pr:pristane; Ph: phytane.

ISOPRENOID ALKANES



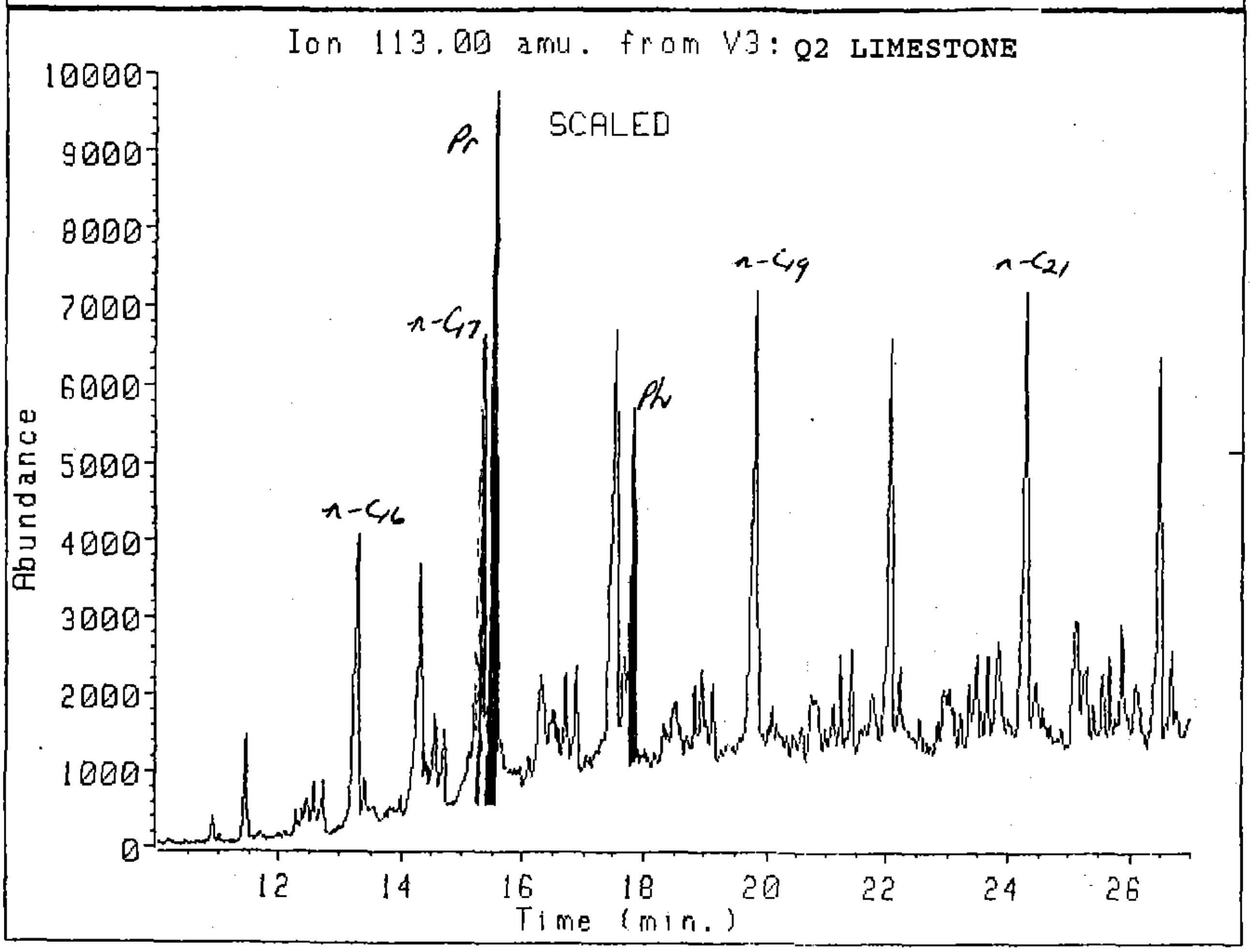


Figure 5b,c. Mass fragmentograms for m/z 113 showing distributions of isoprenoid alkanes in Q1 and Q2. Pr: pristane; Ph: phytane.

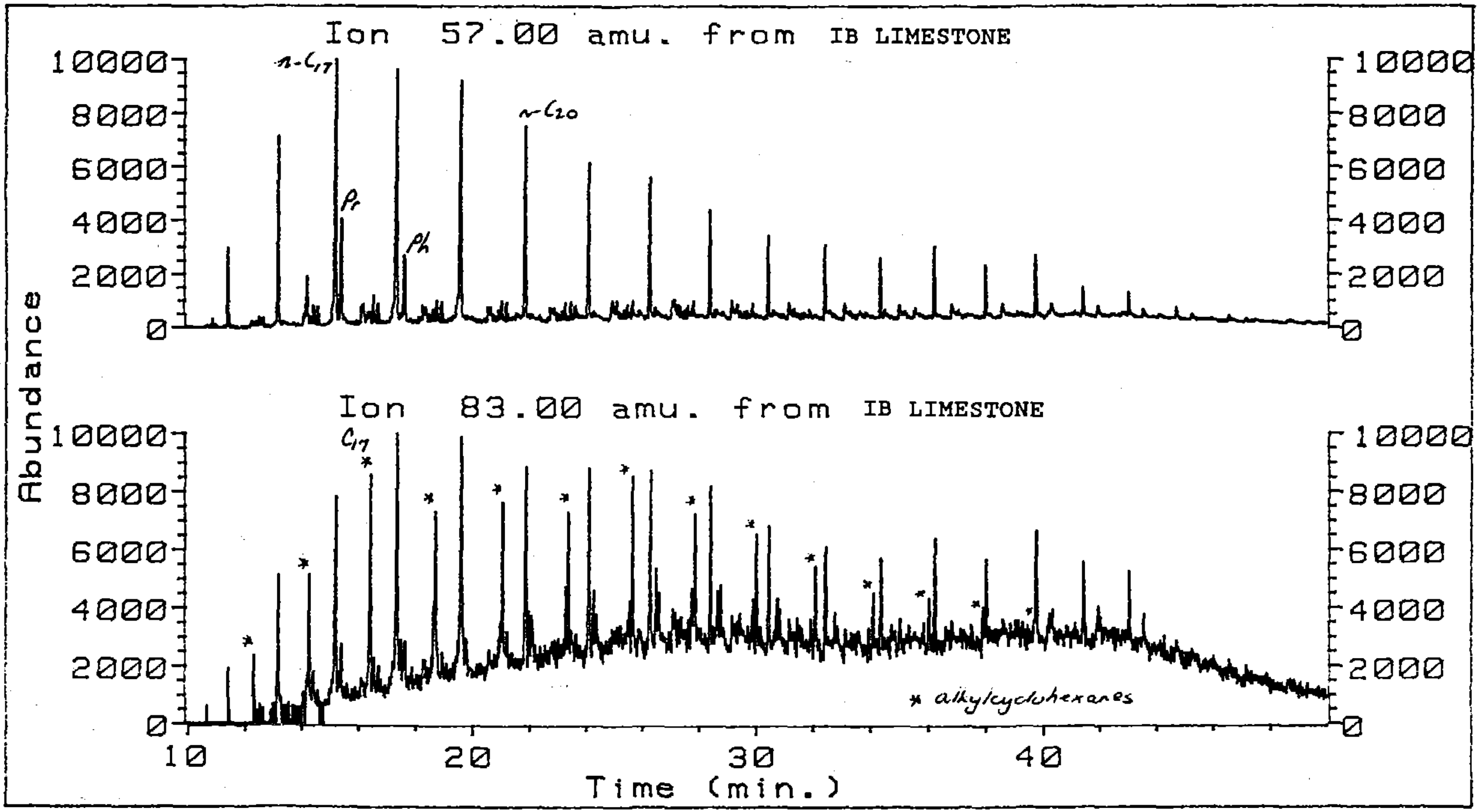


Figure 6a. Mass fragmentograms for m/z 57 (alkanes) and m/z 83 (alkyl cyclohexanes) in sample IB.

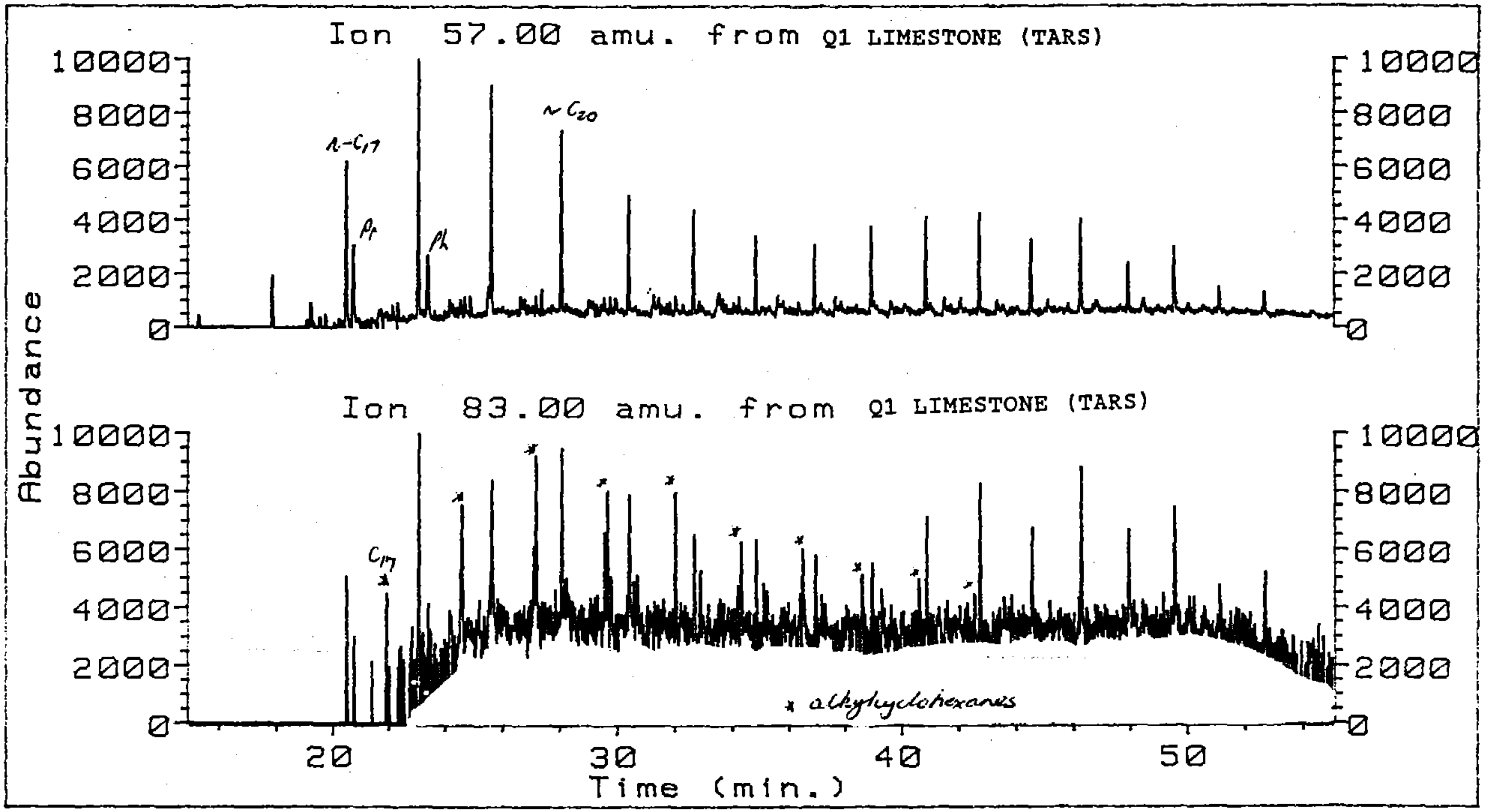


Figure 6b. Mass fragmentograms for m/z 57 (alkanes) and m/z 83 (alkyl cyclohexanes) in sample Q1.

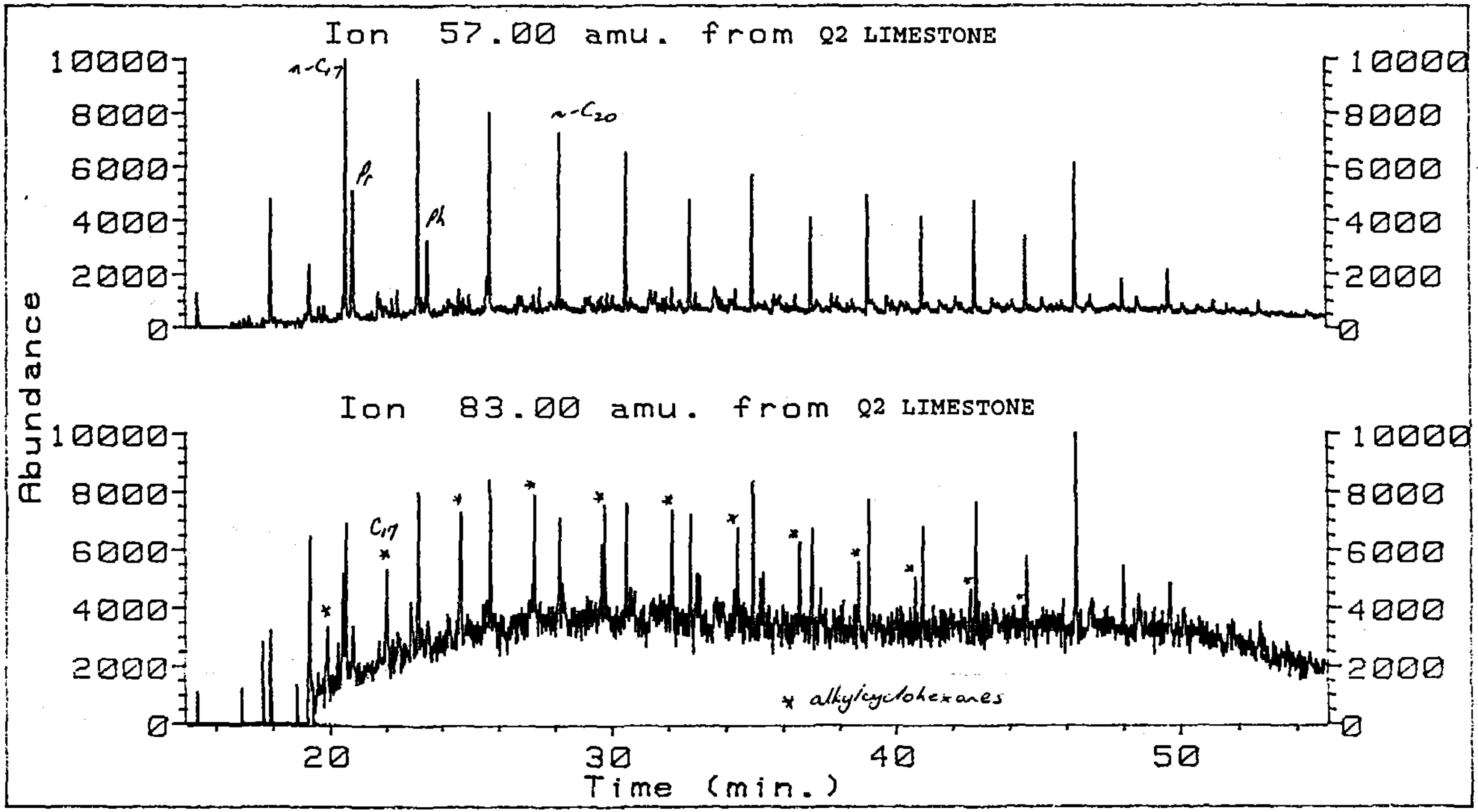


Figure 6c. Mass fragmentograms for m/z 57 (alkanes) and m/z 83 (alkyl cyclohexanes) in sample Q2.

(iii) Pentacyclic triterpanes.

Distributions of hopanes in each of the samples were very similar and typical of those found in mature sediments and crude oils. Hopanes having an "immature" $\beta\beta$ stereochemistry or unsaturated hopenes were not detected or were trace constituents. Mass fragmentograms for m/z 191 are shown in Figures 7, 9 and 11.

Each of the samples contained hopanes extending from C_{27} to C_{35} with the C_{35} extended hopane of similar abundance to the C_{34} component.

Several features of the hopane distributions can be used to ascertain the thermal maturity of the samples. In the extended hopanes (i.e. $>C_{30}$) the 22S epimer is more abundant than the 22R epimer and typically comprises 56-60% of the total 22S plus 22R isomers in mature sediments (Table 2). These isomers isomerise to an equilibrium mixture at maturities well before the oil window, and so are little value for comparing mature samples.

None of the samples showed an anamalous ratio of the 22R and 22S epimers of the C_{31} hopane as had been found in most of the suspected seep samples. Further studies on the seep samples have shown that these anomalous values are not due to a co-eluting compound but reflect high concentrations of naturally-occurring C_{31} 22R hopane epimer in the Bruny Island sediments. The C_{30} polycyclic alkane gammacerane, which can co-elute with the C_{31} hopane, was not detected.

Moretanes are very much less abundant than 17α(H)-hopanes (Table 2). This is typical of sediments within the oil window, but the moretane concentrations seem unusually low even for a mature sediment. The identification of the C_{30} moretane was confirmed by coinjection with an authentic standard (Chiron Labs).

The ratio of the two C_{27} hopanes T_s and T_m is a sensitive indicator of thermal maturity. In each case, T_s was slightly less abundant than T_m (Table 2) which is typical of oils generated at vitrinite reflectance values less than 0.7. Similar values were obtained for several of the suspected seep samples from Bruny Island (Volkman, 1987).

Tricyclic alkanes are comparatively minor constituents of these samples as judged by peak areas in the m/z 191 mass fragmentograms. These compounds dominate the m/z 191 mass fragmentograms obtained from Tasmanites (unpublished data) and should be a useful parameter for distinguishing any petroleum generated from these very different sediment types.

The unusual hopane bisnorhopane, which occurs in some Australian crudes was not detected in any of the samples. Demethylated hopanes were not detected in any of the samples using m/z 177 mass fragmentograms (Figures 8, 10 and 12). These are commonly associated with highly biodegraded residues of crude oil (Volkman et al., 1983).

TABLE 3. IDENTIFICATIONS OF PEAKS IN HOPANE (M/Z 191) AND METHYL HOPANE (M/Z 205) MASS FRAGMENTOGRAMS

PEAK		COMPOUND
1	C_{27}	18α(H)-22,29,30-trisnorneohopane (T_s)
2	C_{27}	17α(H)-22,29,30-trisnorhopane (T_m)
3	C_{29}	17α(H),21β(H)-norhopane
4	C_{29}	17β(H),21α(H)-norhopane
5	C_{30}	17α(H),21β(H)-hopane
6	C_{30}	17β(H),21α(H)-hopane
7	C_{31}	(22S)-17α(H),21β(H)-hopane
8	C_{31}	(22R)-17α(H),21β(H)-hopane
9	C_{32}	(22S)-17α(H),21β(H)-hopane
10	C_{32}	(22R)-17α(H),21β(H)-hopane
11	C_{33}	(22S)-17α(H),21β(H)-hopane
12	C_{33}	(22R)-17α(H),21β(H)-hopane
13	C_{34}	(22S)-17α(H),21β(H)-hopane
14	C_{34}	(22R)-17α(H),21β(H)-hopane
15	C_{35}	(22S)-17α(H),21β(H)-hopane
16	C_{35}	(22R)-17α(H),21β(H)-hopane
M1	C_{28}	18α(H)-x-methyl-22,29,30-trisnorneohopane
M2	C_{28}	17α(H)-x-methyl-22,29,30-trisnorhopane
M3	C_{30}	17α(H),21β(H)-x-methyl-norhopane
M4	C_{30}	17β(H),21α(H)-x-methyl-norhopane
M5	C_{31}	17α(H),21β(H)-x-methylhopane
M6	C_{31}	17β(H),21α(H)-x-methylhopane
M7	C_{32}	(22S)-17α(H),21β(H)-x-methylhopane
M8	C_{32}	(22R)-17α(H),21β(H)-x-methylhopane
M9	C_{33}	(22S)-17α(H),21β(H)-x-methylhopane
M10	C_{33}	(22R)-17α(H),21β(H)-x-methylhopane
M11	C_{34}	(22S)-17α(H),21β(H)-x-methylhopane
M12	C_{34}	(22R)-17α(H),21β(H)-x-methylhopane
M13	C_{35}	(22S)-17α(H),21β(H)-x-methylhopane
M14	C_{35}	(22R)-17α(H),21β(H)-x-methylhopane
M15	C_{36}	(22S)-17α(H),21β(H)-x-methylhopane
M16	C_{36}	(22R)-17α(H),21β(H)-x-methylhopane

"x" = 2 or 3.

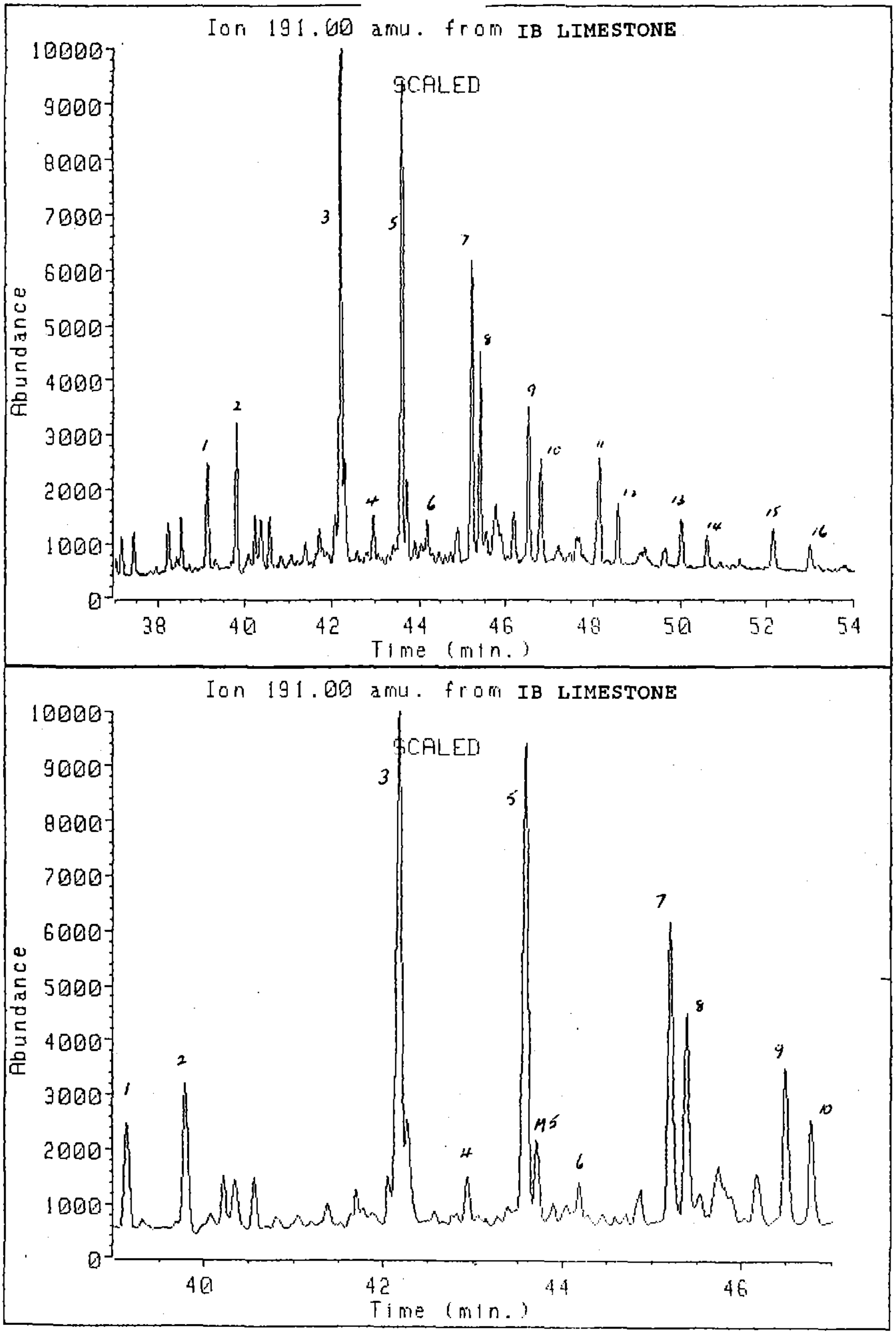


Figure 7a,b. Mass fragmentograms for m/z 191 over two time windows showing distributions of hopanes in sample IB.

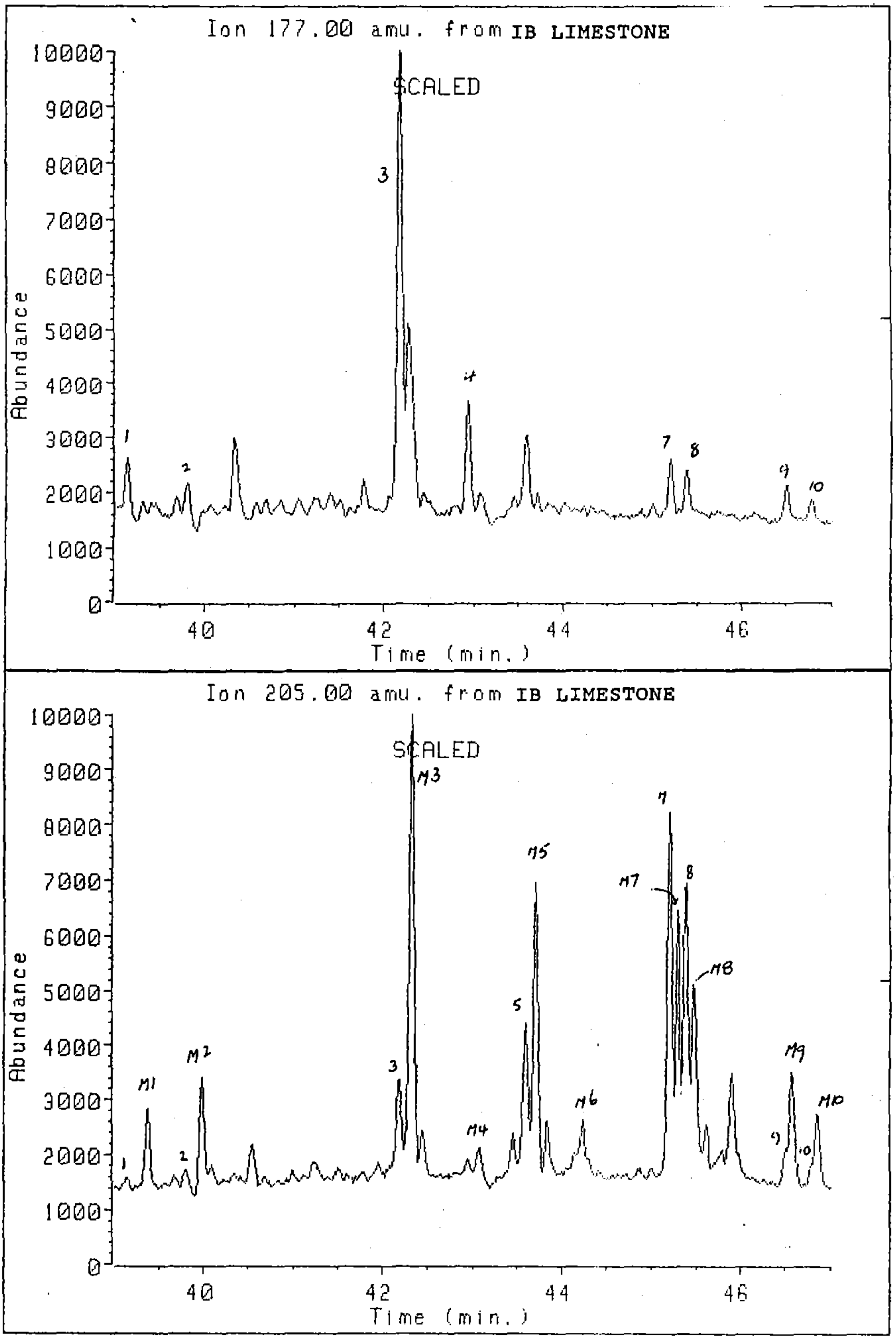


Figure 8a,b. Mass fragmentograms for m/z 177 (demethylated hopanes) and m/z 205 (methyl hopanes) in sample IB.

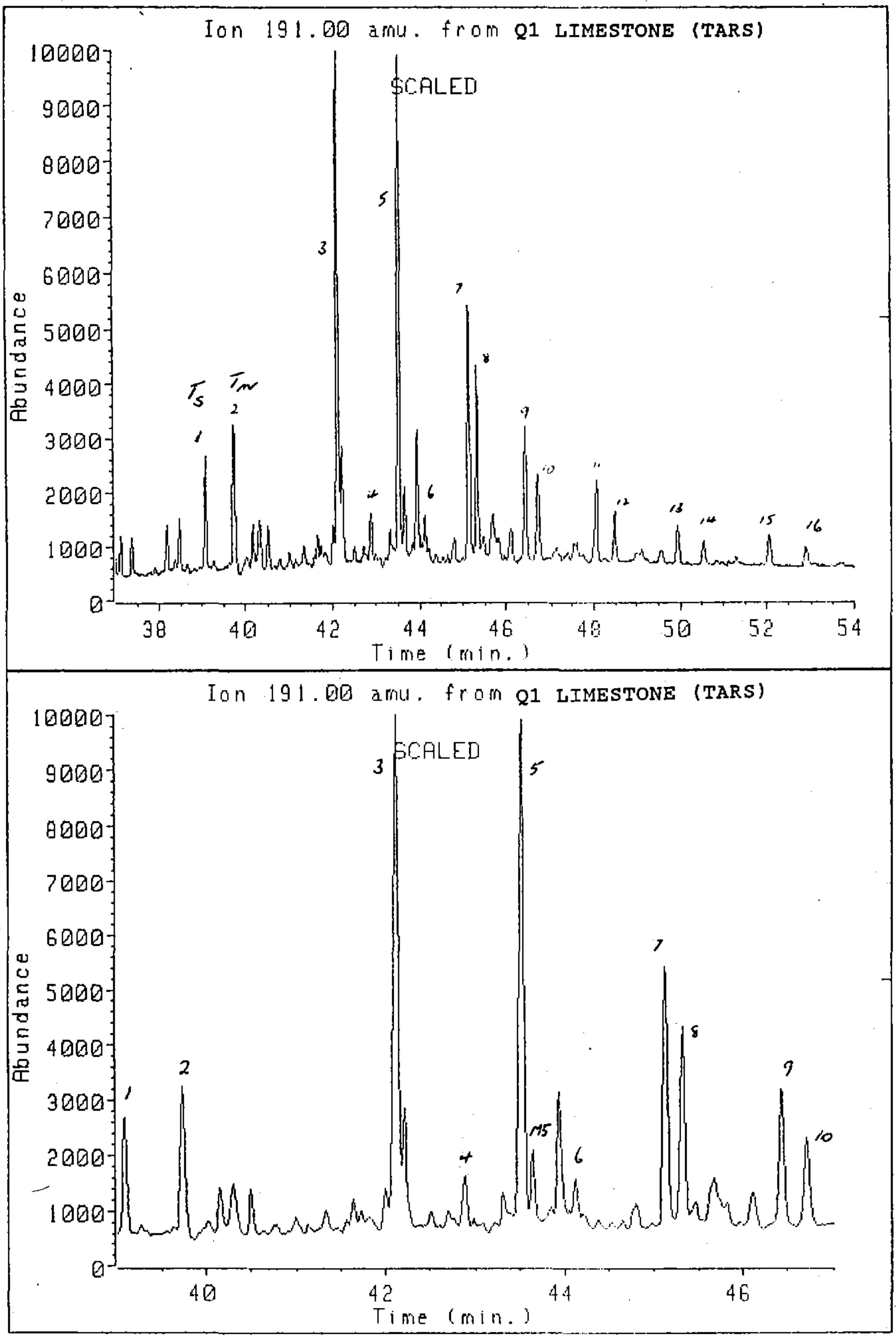


Figure 9a,b. Mass fragmentograms for m/z 191 over two time windows showing distributions of hopanes in sample Q1.

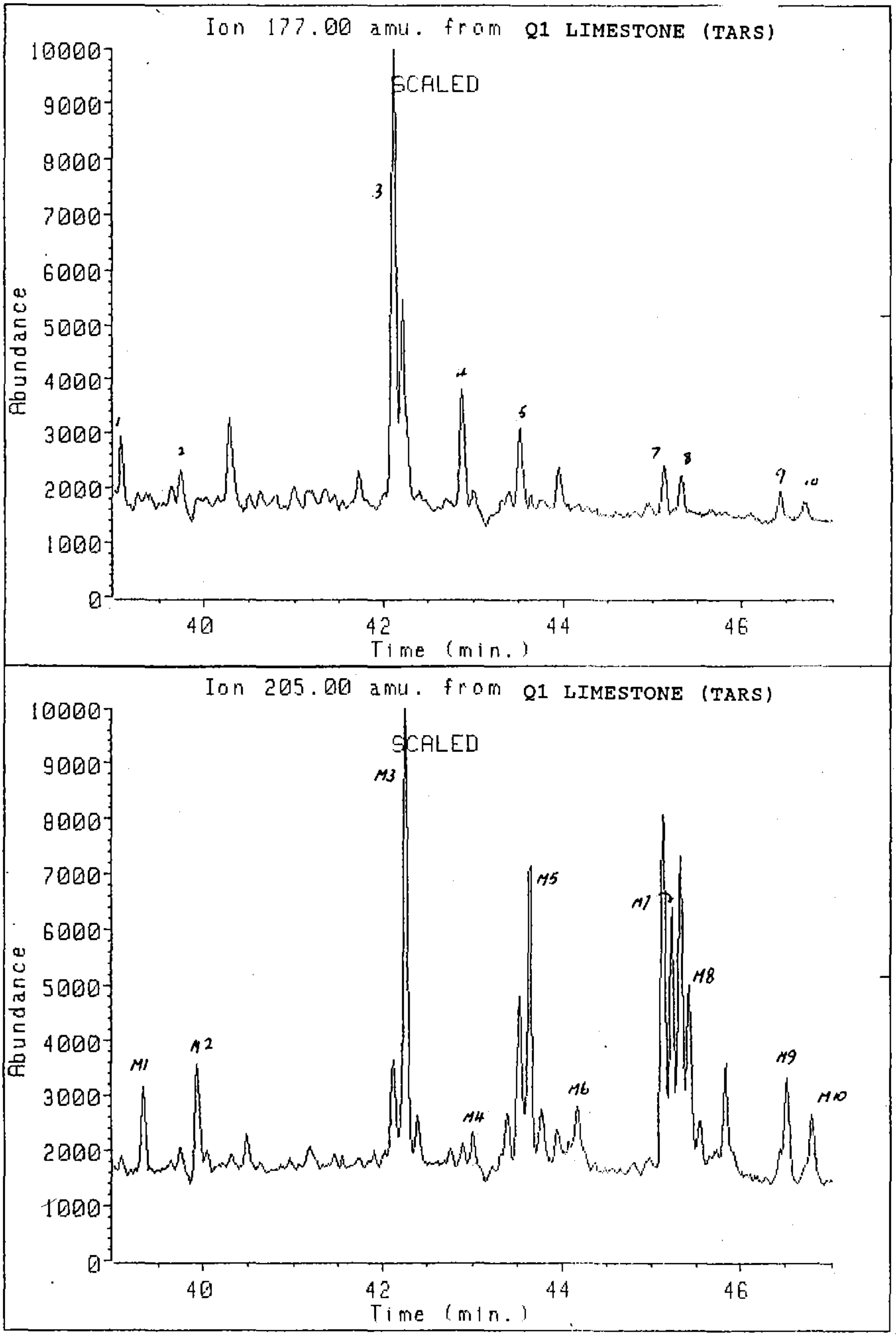


Figure 10a,b. Mass fragmentograms for m/z 177 (demethylated hopanes) and m/z 205 (methyl hopanes) in sample Q1.

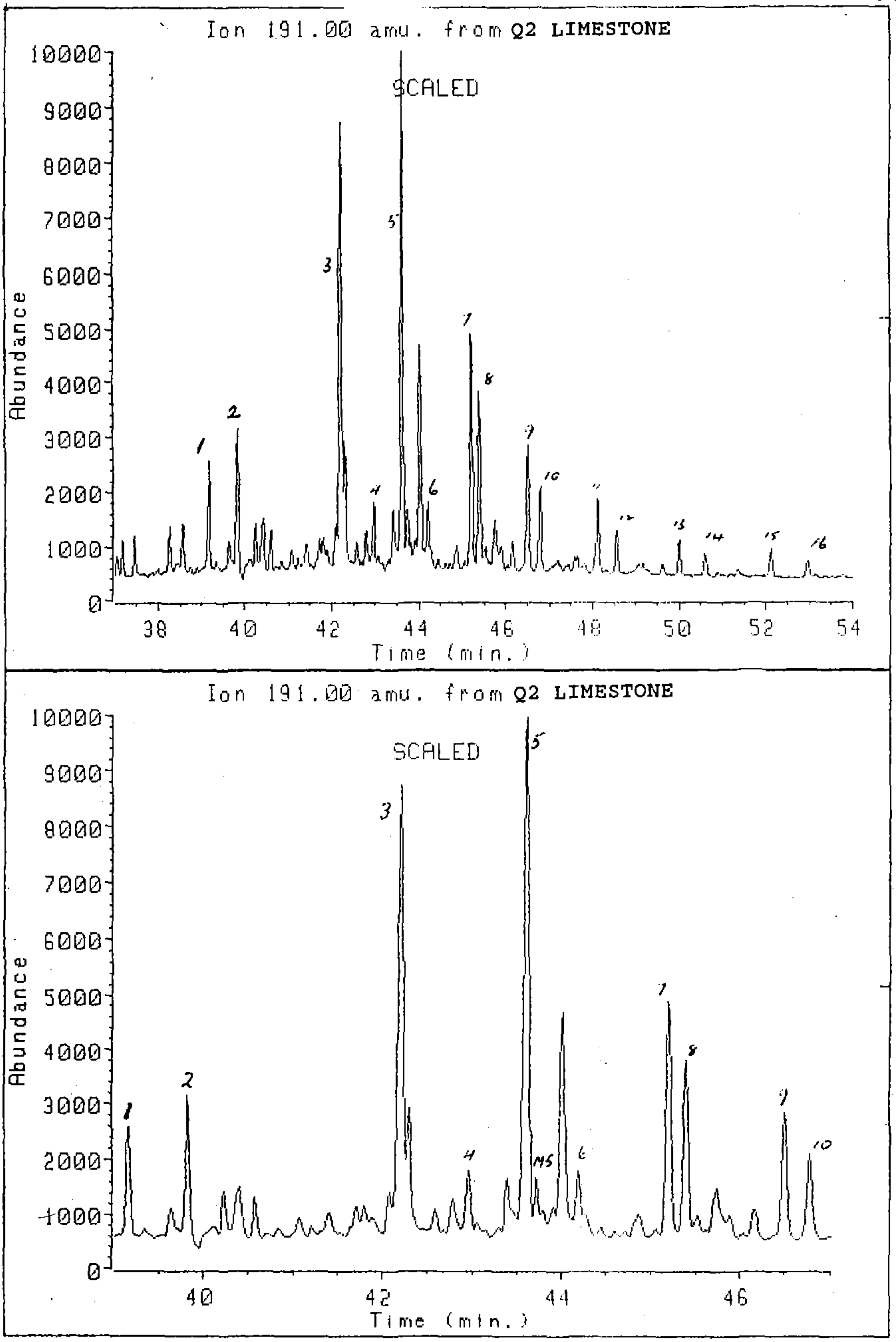


Figure 11a,b. Mass fragmentograms for m/z 191 over two time windows showing distributions of hopanes in sample Q2.

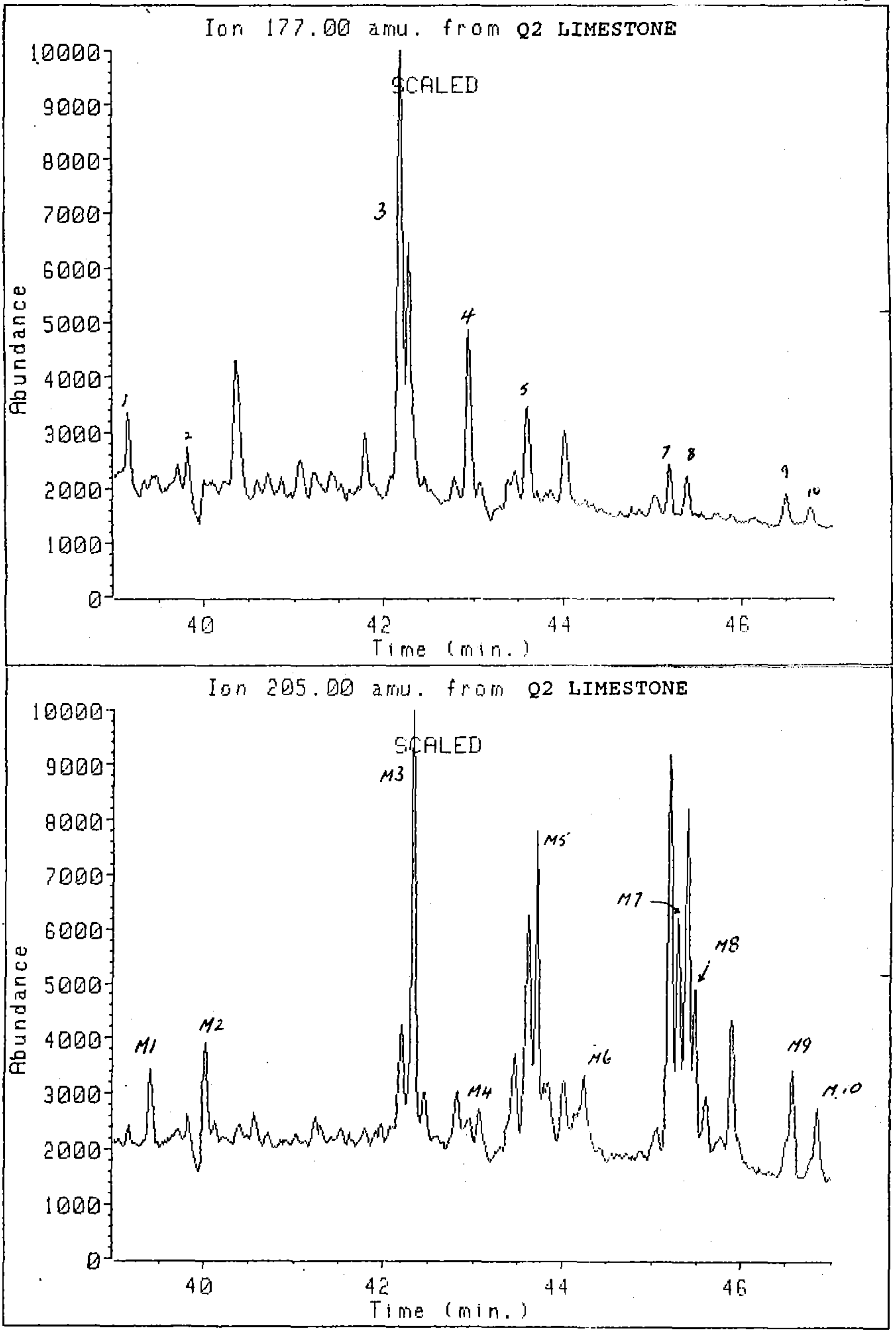


Figure 12a,b. Mass fragmentograms for m/z 177 (demethylated hopanes) and m/z 205 (methyl hopanes) in sample Q2.

(iv) Methyl hopanes.

All 3 samples contained a series of methyl hopanes ranging from C_{28} to C_{36} (Figure 13). These compounds are not apparent in the m/z 191 mass fragmentograms used to characterise hopane distributions since the addition of the methyl group increases the mass of this fragment to m/z 205. The distribution of methyl hopanes was very similar to that of the hopanes and the ratio of the two C_{28} components closely matched the T_s/T_m ratio. Hoffmann et al. (1987) tentatively assigned the position of the methyl group as C-3 but authentic standards are not yet available to confirm that it is at C-3 rather than C-2.

Methyl hopanes are not common in crude oils and many oils do not contain them at all. Only a few species of bacteria make 2-methyl and 3-methyl hopanoids and it appears that these bacterial types are restricted in their distribution. Methyl hopanes are not unique to Ordovician sediments but they do appear to be a characteristic feature of the hydrocarbons obtained from all Ordovician limestones analysed to date.

A limited search has been made for these compounds in sediments from the D'Entrecasteaux Channel and nearby coastal areas. Several samples not only contain the series of methyl hopanes but their abundance relative to hopanes is almost identical to that found in the limestones (Figure 13). The sample shown from the D'Entrecasteaux Channel was obtained mid-way between Dennes Point and Piersons Point. The other sample shown was collected mid-way up North West Bay. The only major difference between these two chromatograms and that obtained from the Ordovician limestone is the higher abundance of peak 8 (C_{31}-hopane) in the two sediment samples. This is almost certainly due to naturally occurring amounts of (22R)-17α(H),21β(H)-homohopane in soils and sediments produced by diagensis of bacterial compounds such as bishomohopanoic acid.

The close similarity of methyl hopane distributions, coupled with data from other biomarker parameters, provides strong circumstantial evidence that much of the petroleum hydrocarbons in the estuarine sediments originates from the Ordovician limestones. A definitive statement cannot be made yet since there has been no study of other potential source rocks to ascertain whether they also contian substantial amounts of these unusual compounds. It will also need to be established that the hydrocarbons do not originate from weathering of the limestones and transport of this material into the marine environment. Preliminary data suggests that the distribution of methyl hopanes in the Channel is patchy as might be expected if their source was from oil seeps.

These compounds were not noticed in the earlier analyses of suspected oil seeps from Bruny Island due to the large amounts of other hopanes contributing to the m/z 205 mass fragmentograms (Volkman, 1987). A re-examination of sample B7 (Figure 13d) showed that the methyl hopanes were indeed present, and the ratio of peaks 7 and M7 was similar to that in the limestone. A re-examination of other samples from Bruny Island for methyl hopanes could provide some very useful data on likely origins for the petroleum hydrocarbons found there.

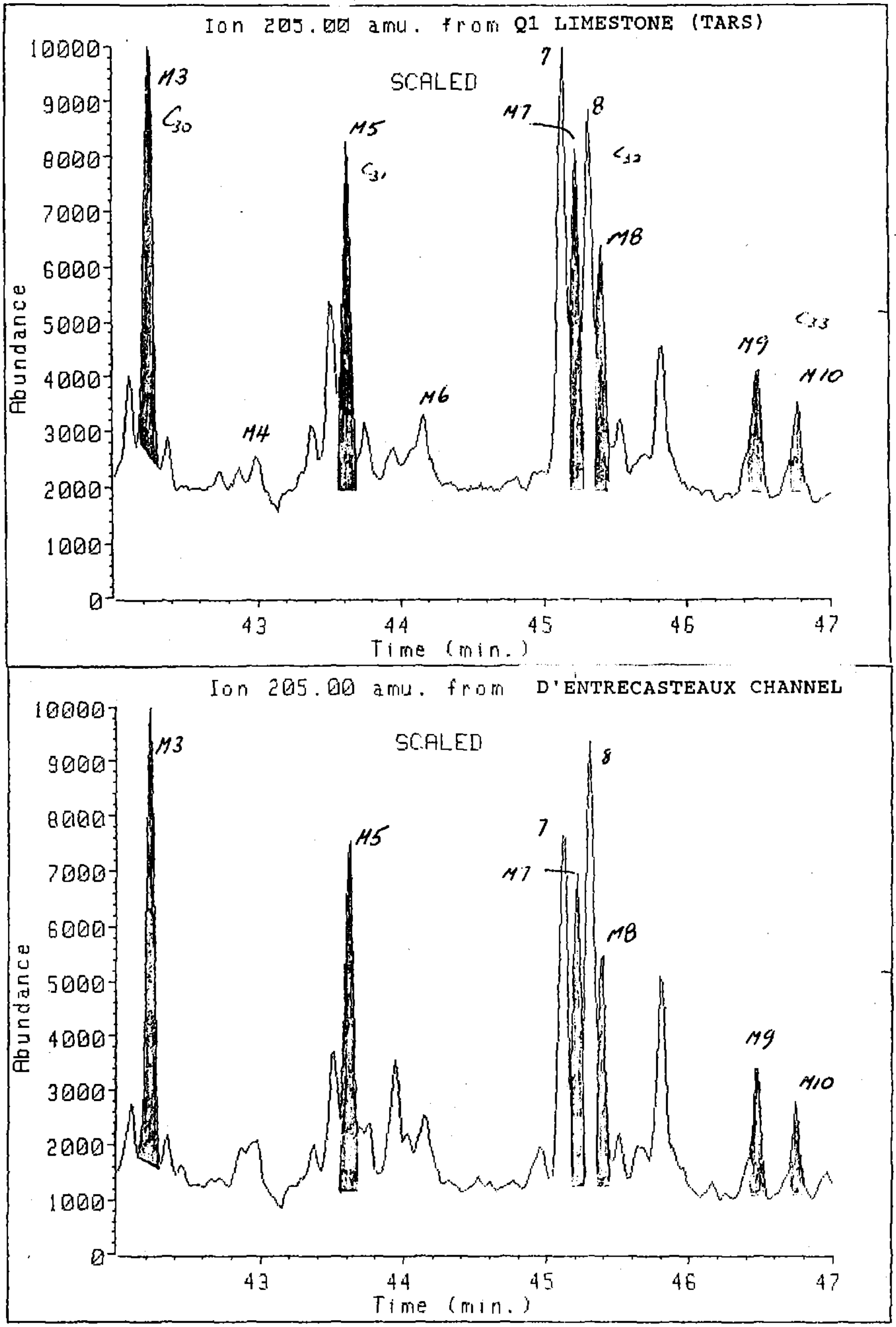


Figure 13a,b. Mass fragmentograms for m/z 205 showing distibution of C_{30}-C_{33} methyl hopanes in sample Q1 and a sediment from the D'Entrecasteaux Channel.

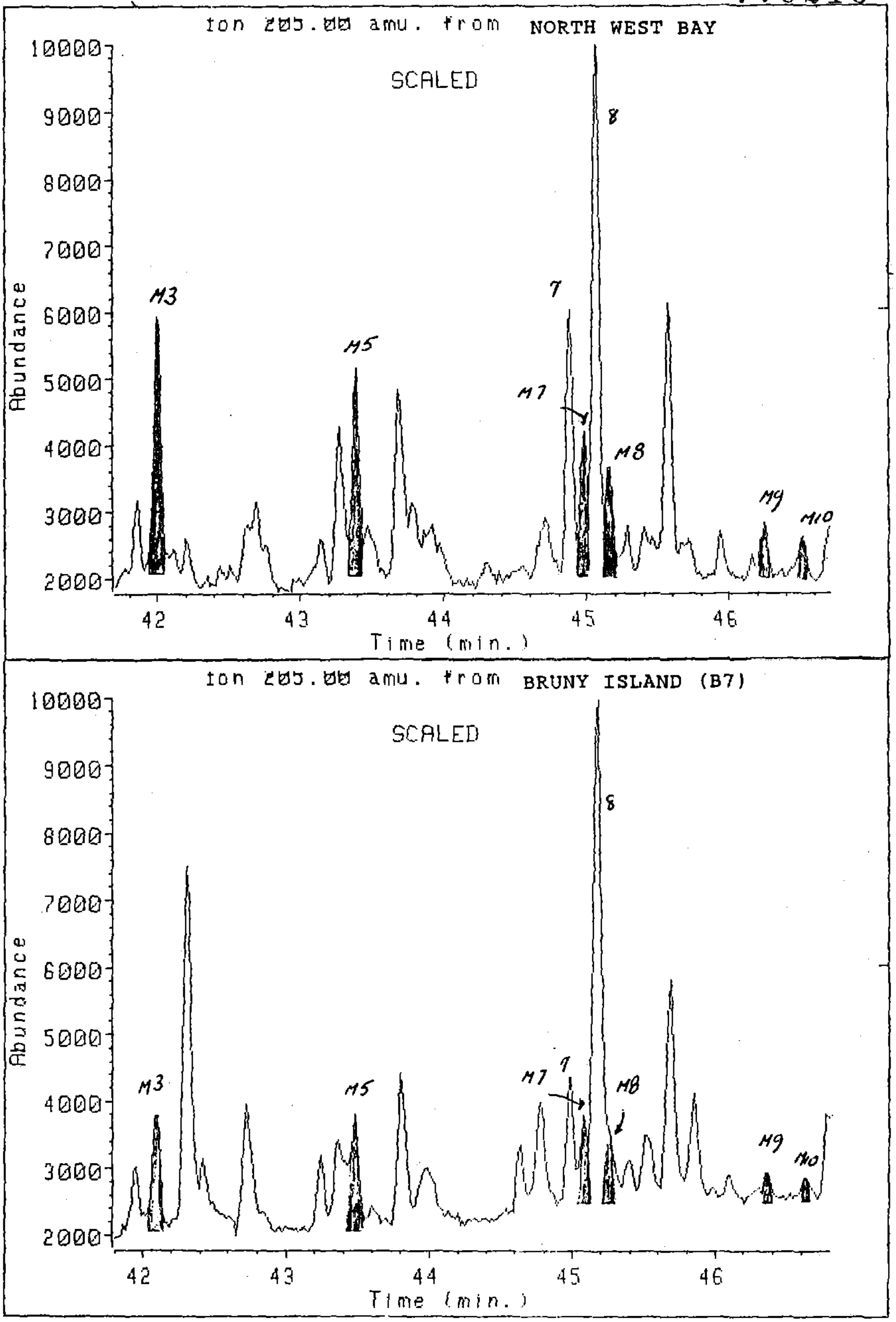


Figure 13c,d. Mass fragmentograms for m/z 205 showing distibution of C_{30}-C_{33} methyl hopanes in a sediment from North West Bay and a suspected seep sample fom Bruny Island.

(v) Steranes.

Distributions of steranes can provide information about the maturity and source of a crude oil. Mass fragmentograms for m/z 217, 218 and 259 are shown in Figures 14-18. Quantitative data for selected isomer ratios are shown in Table 2.

Each sample contains a similar distribution of C_{27} - C_{29} steranes (Figures 14-16) and slightly lesser amounts of C_{21} and C_{22} steranes (Figures 17 and 18). There are only very slight variations in the sterane source parameters of the 3 samples (Table 2). The occurrence of approximately equal amounts of C_{27} and C_{29} steranes is very similar to ratios obtained for suspected oil seep samples from Bruny Island.

Maturity parameters were very similar for all of the samples. The ratios of "geological" to "biological" isomers (Table 2) is typical of thermally mature sediments. The ratio of the "geological" 20S $\alpha\alpha\alpha$-isomer to the "biological" 20R $\alpha\alpha\alpha$-isomer (Table 1) suggests that the limestones have been heated to an equivalent vitrinite reflectance of about 0.60-0.65.

The amount of diasteranes (rearranged steranes) relative to steranes (Figures 14-16) varied slightly between the three samples. C_{27} and C_{29} diasteranes were present in similar amounts with C_{28} diasteranes about half as abundant (Figure 18). These compounds are typically abundant where the source rocks contain large amounts of clays which catalyse the steroid backbone rearrangement. However, their occurrence in these carbonates shows that clays are not essential for their formation.

4-Methyl steranes were not detected in any of the samples. These compounds are significant constituents of oil seep bitumens found off South Australia.

TABLE 4. IDENTIFICATION OF PEAKS IN STERANE (M/Z 217 AND 218) AND DIASTERANE (M/Z 259) MASS FRAGMENTOGRAMS.

PEAK		COMPOUND
1	C_{27}	(20S)-5α(H),14α(H),17α(H)-cholestane
2	C_{27}	(20R)-5α(H),14β(H),17β(H)-cholestane
3	C_{27}	(20S)-5α(H),14β(H),17β(H)-cholestane
4	C_{27}	(20R)-5α(H),14α(H),17α(H)-cholestane
5	C_{28}	(20S)-5α(H),14α(H),17α(H)-24-methylcholestane
6	C_{28}	(20R)-5α(H),14β(H),17β(H)-24-methylcholestane
7	C_{28}	(20S)-5α(H),14β(H),17β(H)-24-methylcholestane
8	C_{28}	(20R)-5α(H),14α(H),17α(H)-24-methylcholestane
9	C_{29}	(20S)-5α(H),14α(H),17α(H)-24-ethylcholestane
10	C_{29}	(20R)-5α(H),14β(H),17β(H)-24-ethylcholestane
11	C_{29}	(20S)-5α(H),14β(H),17β(H)-24-ethylcholestane
12	C_{29}	(20R)-5α(H),14α(H),17α(H)-24-ethylcholestane
D1	C_{27}	(20S)-13β(H),17α(H)-diasterane
D2	C_{27}	(20R)-13β(H),17α(H)-diasterane
D3	C_{28}	(20S)-13β(H),17α(H)-diasterane
D4	C_{28}	(20R)-13β(H),17α(H)-diasterane
D5	C_{29}	(20S)-13β(H),17α(H)-diasterane
D6	C_{29}	(20R)-13β(H),17α(H)-diasterane

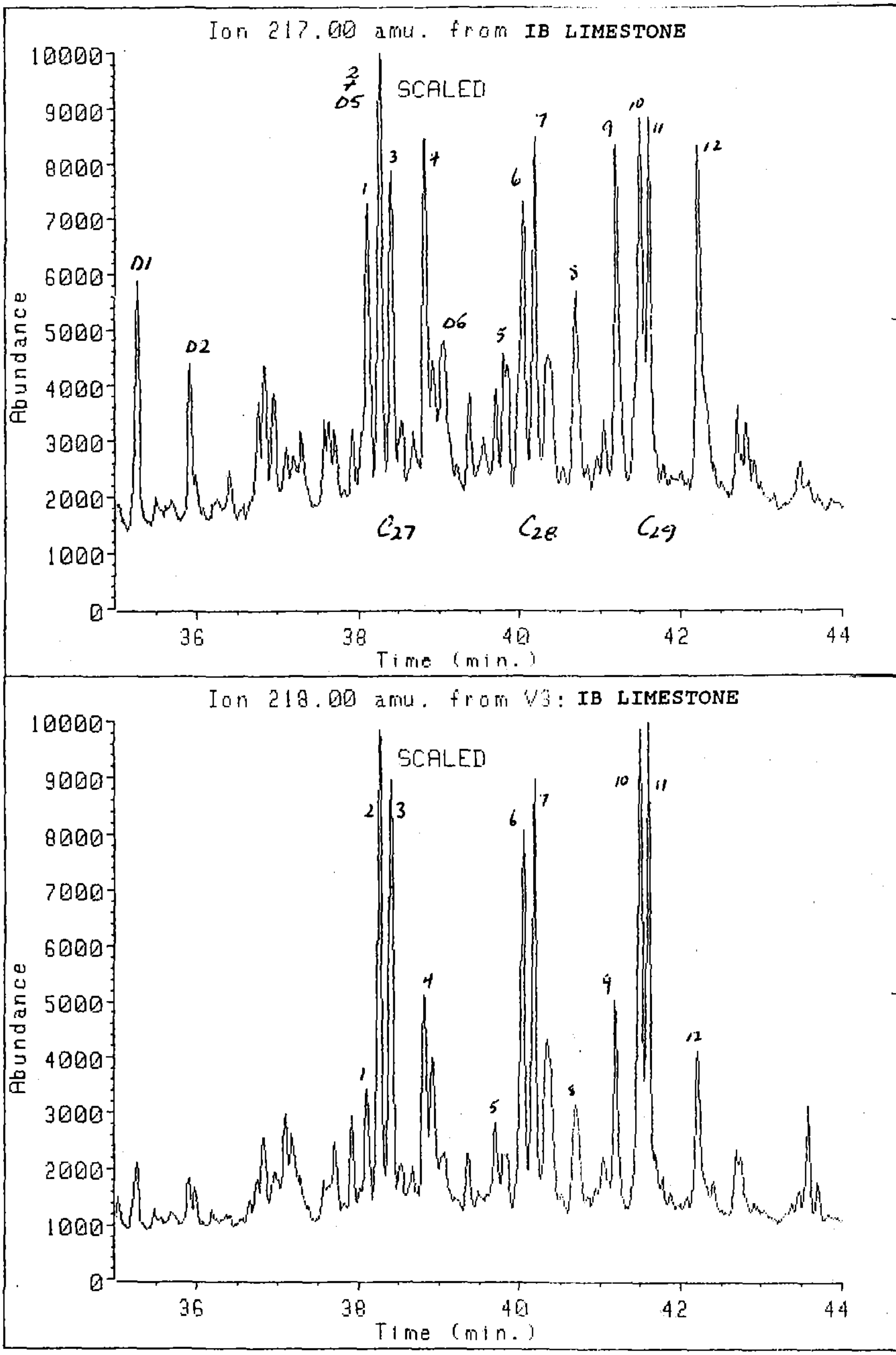


Figure 14a,b. Mass fragmentograms for m/z 217 and 218 showing distributions of C_{26}-C_{30} steranes and diasteranes in sample IB.

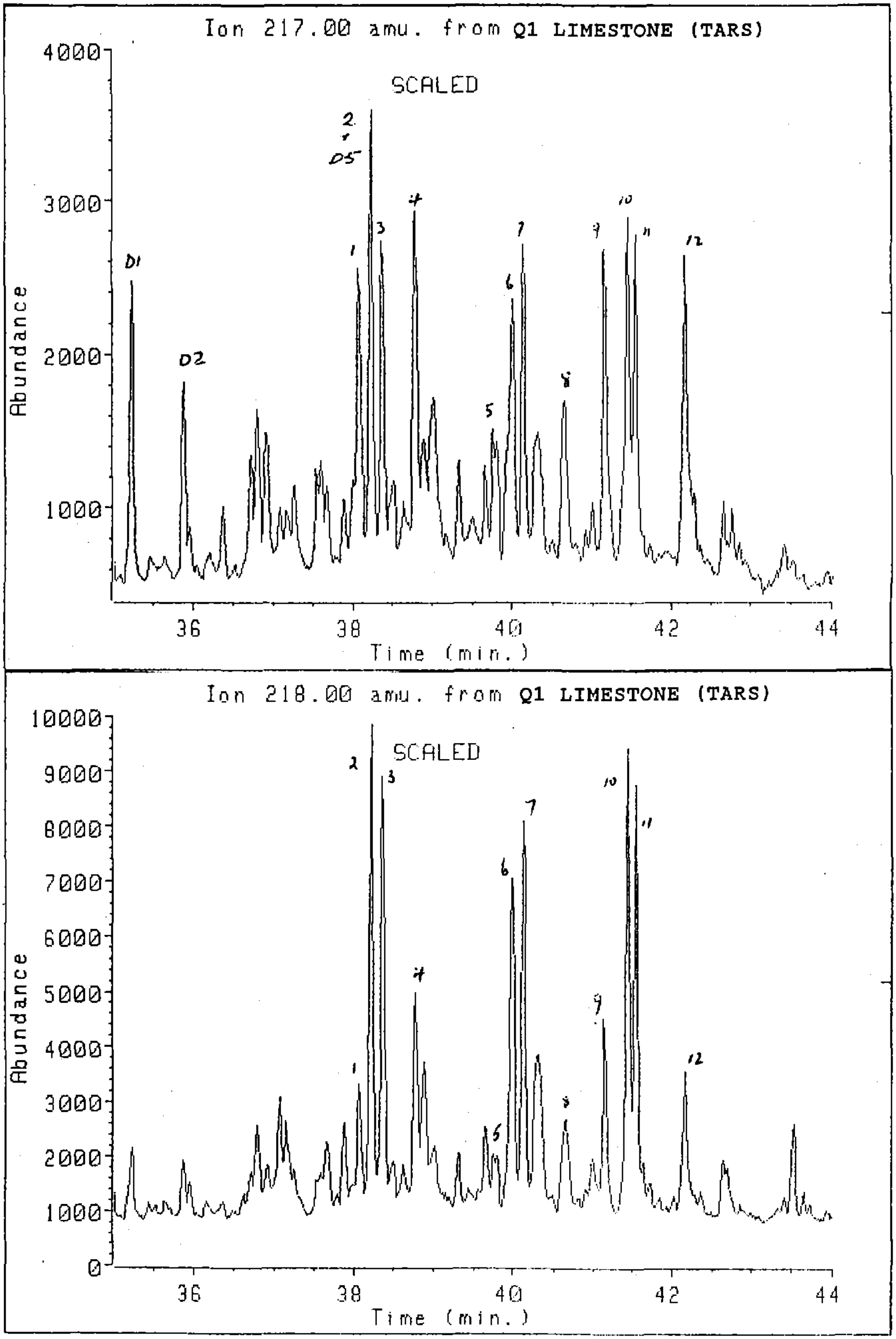


Figure 15a,b. Mass fragmentograms for m/z 217 and 218 showing distributions of C_{26}-C_{30} steranes and diasteranes in sample Q1.

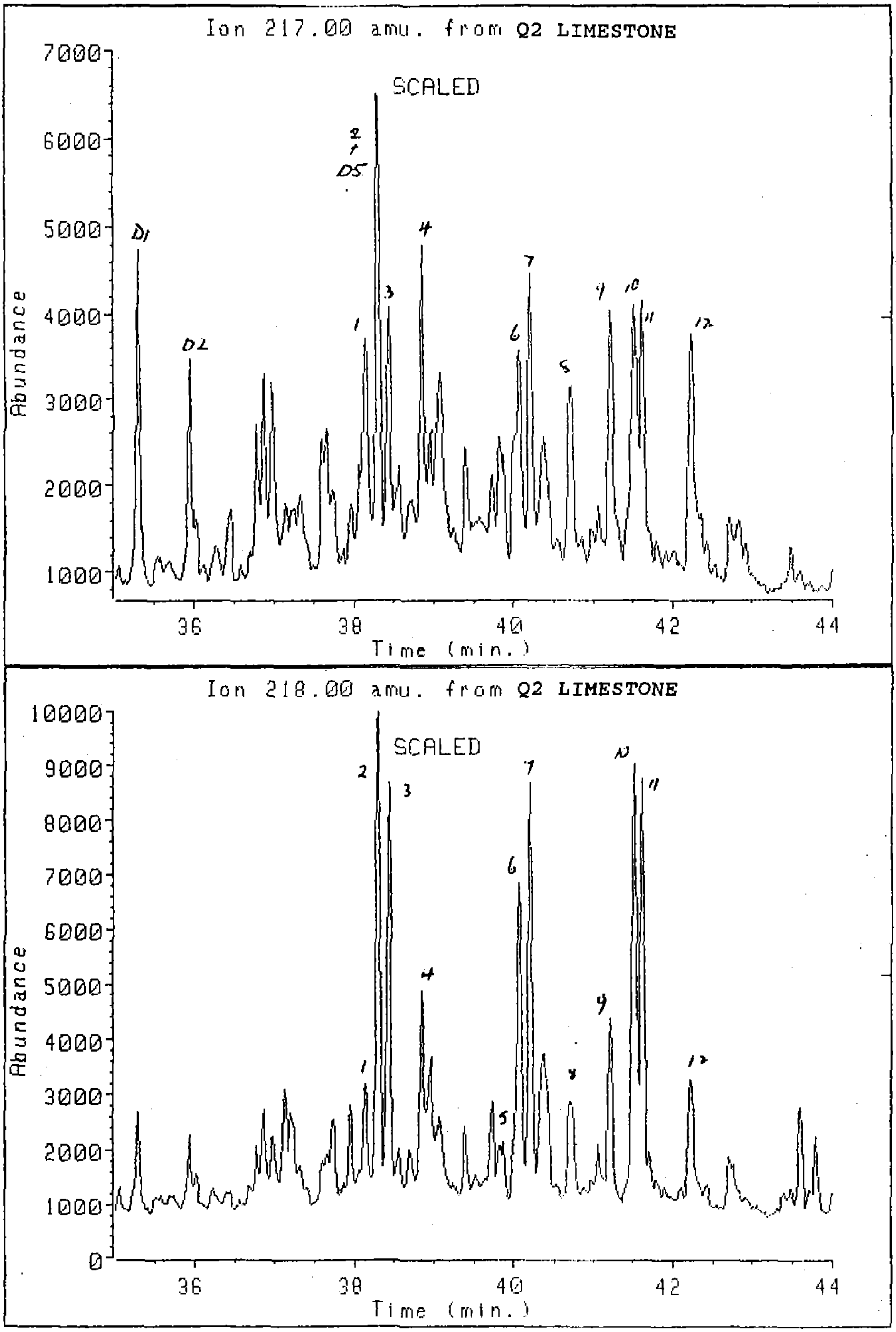


Figure 16a,b. Mass fragmentograms for m/z 217 and 218 showing distributions of C_{26}-C_{30} steranes and diasteranes in sample Q2.

STERANES

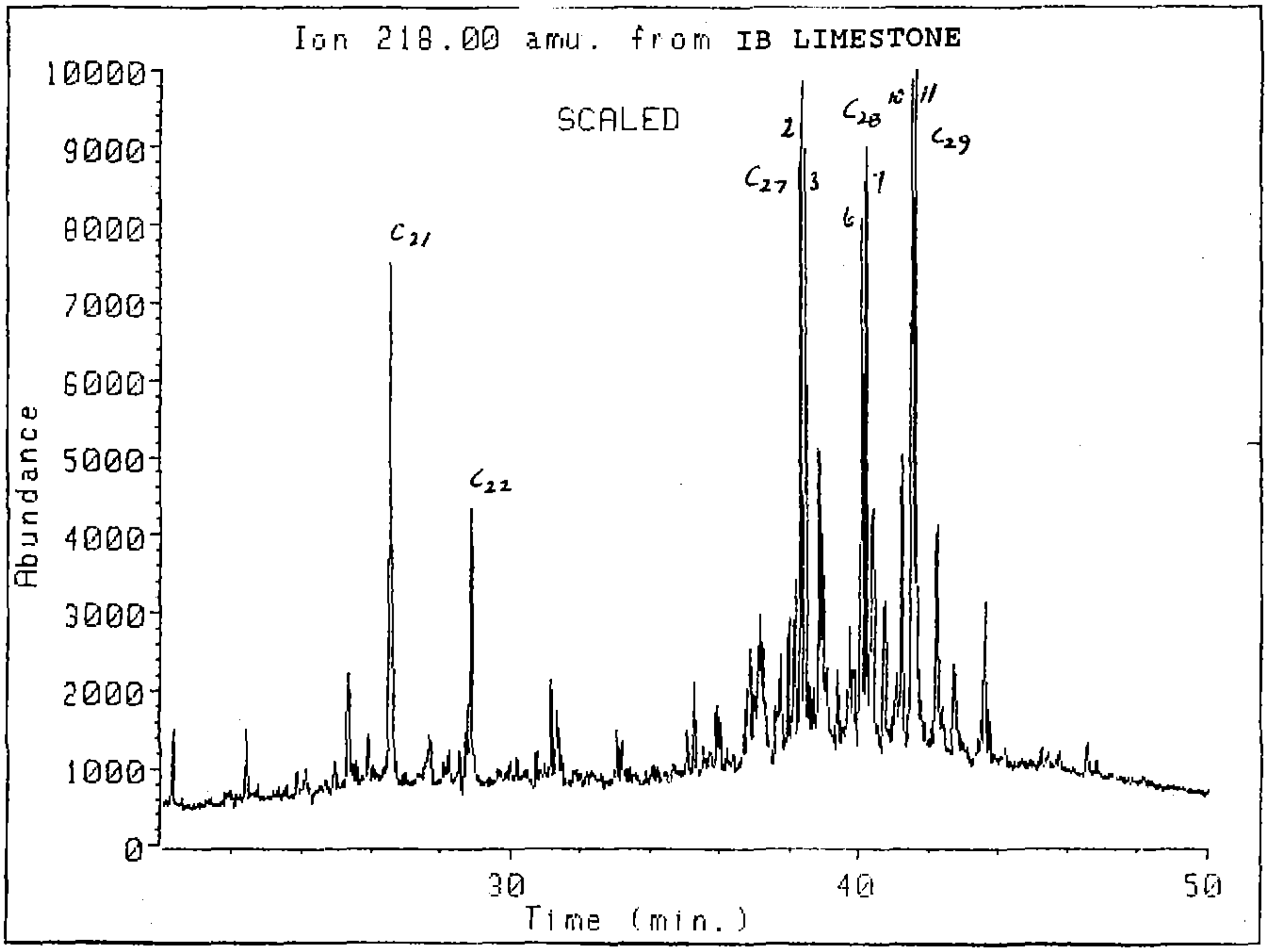


Figure 17a. Mass fragmentogram for m/z 218 showing distribution of C_{21}-C_{30} steranes in sample IB.

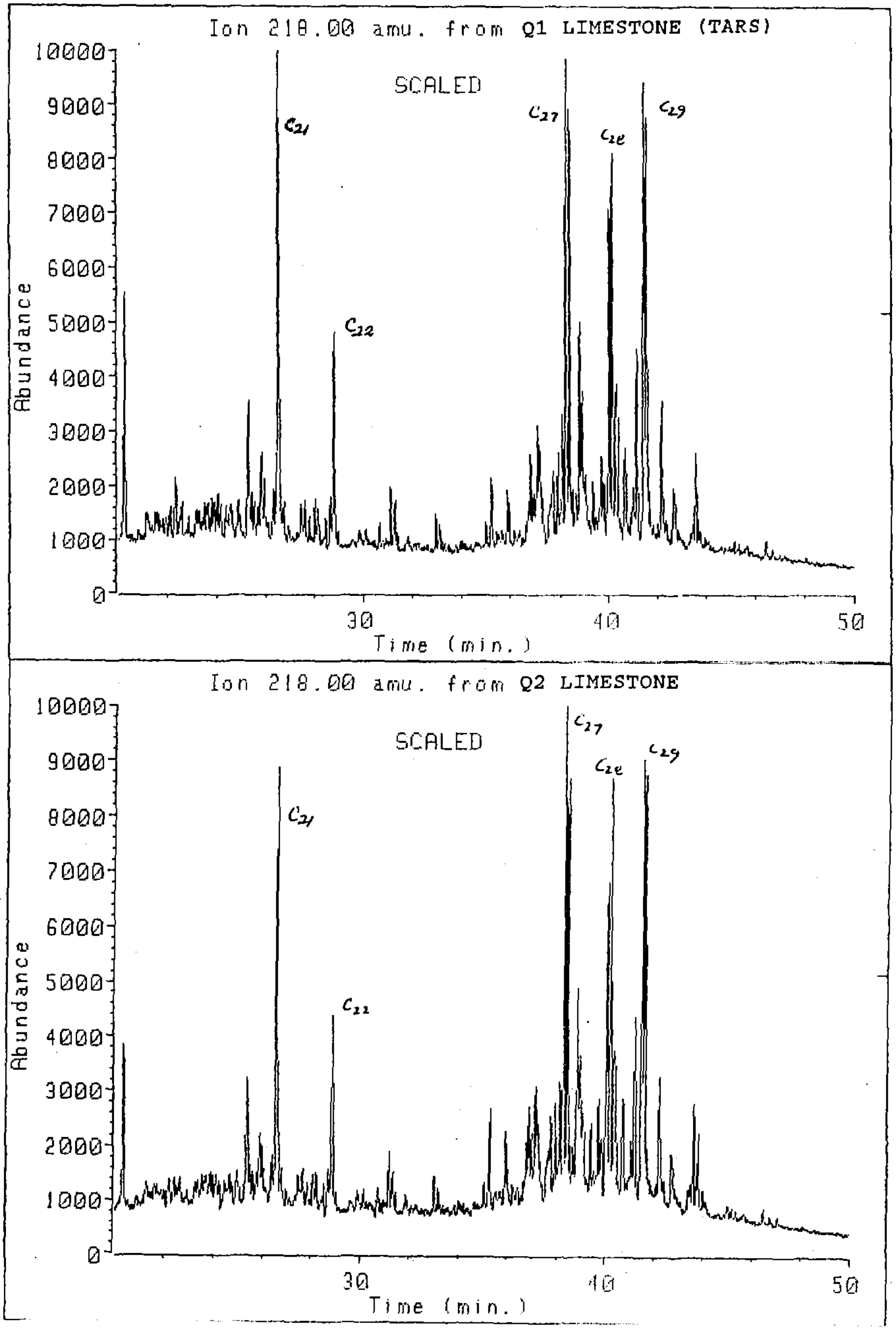


Figure 17b,c. Mass fragmentograms for m/z 218 showing distribution of C_{21}–C_{30} steranes in samples Q1 and Q2.

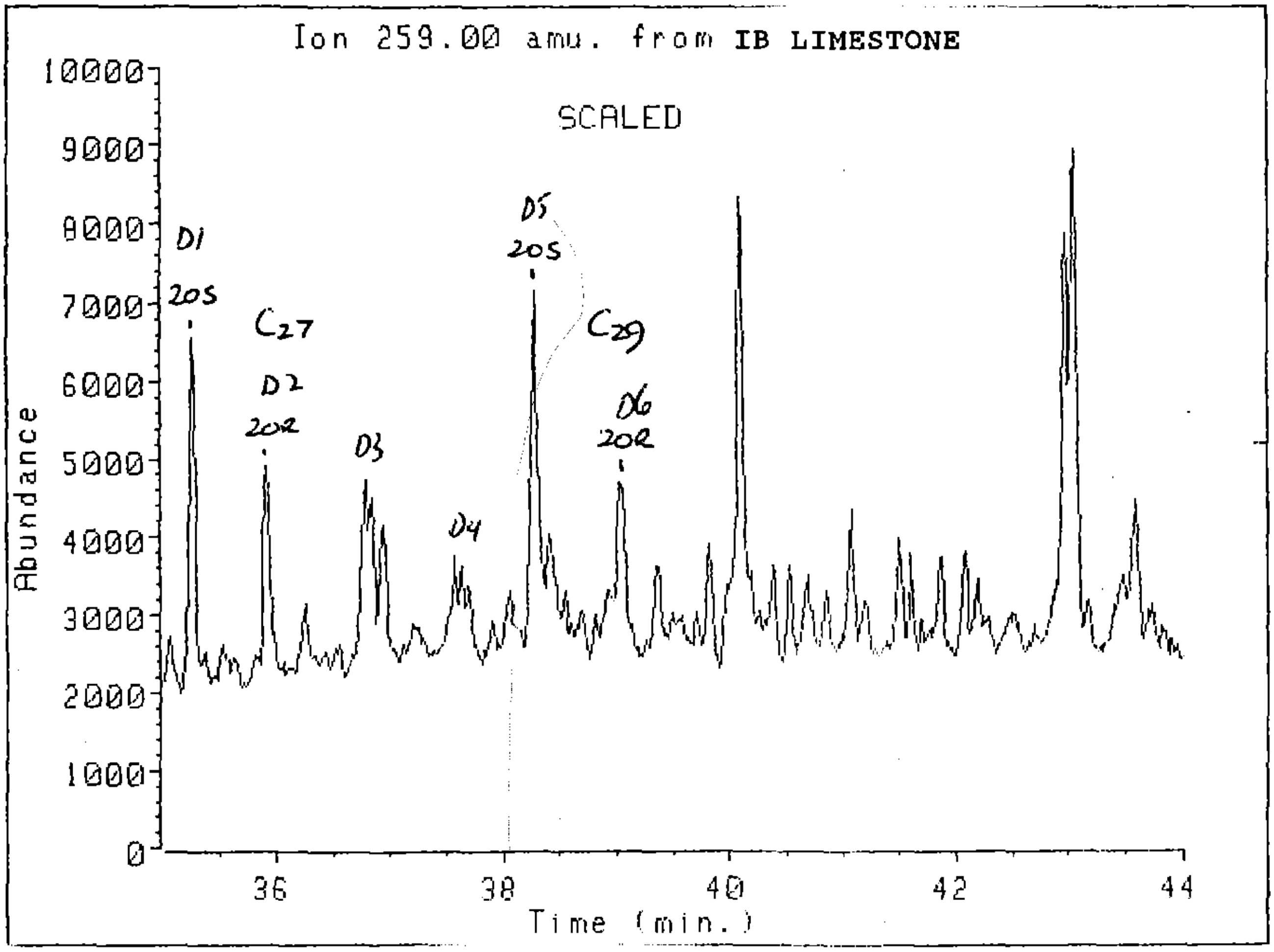


Figure 18a. Mass fragmentogram for m/z 259 showing distribution of rearranged steranes (diasteranes) in sample IB.

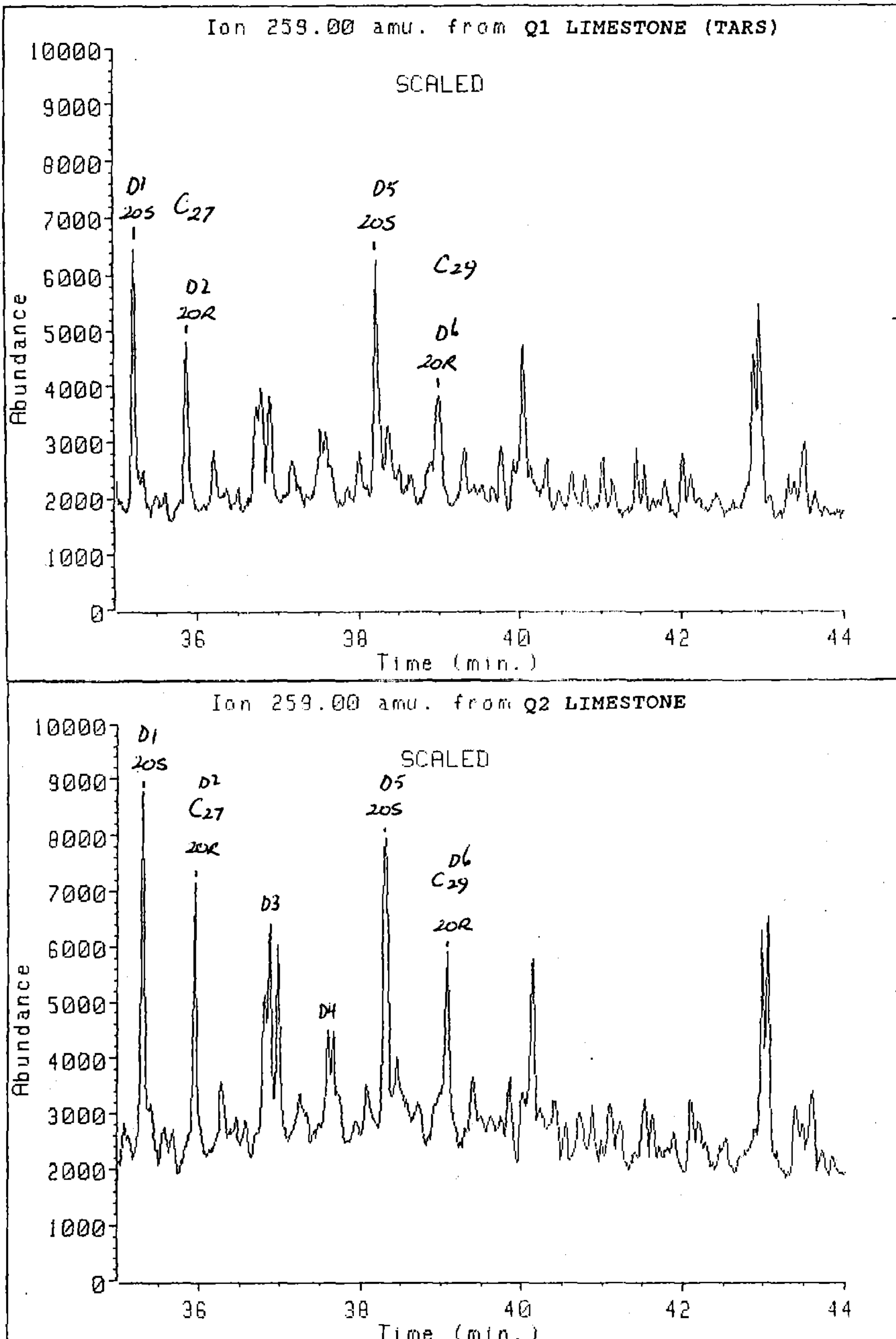


Figure 18b,c. Mass fragmentograms for m/z 259 showing distribution of rearranged steranes (diasteranes) in sample Q1 and Q2.

REFERENCES

Hoffmann, C.F., C.B. Foster, T.G. Powell and R.E. Summons (1987). Hydrocarbon biomarkers from Ordovician sediments and the fossil alga *Gloeocapsomorpha prisca* Zalessky 1917. *Geochim. Cosmochim. Acta.* 51, 2681-2697.

Volkman J. K., R. Alexander, R. I. Kagi, and G. W. Woodhouse (1983). Demethylated hopanes in crude oils and their applications in petroleum geochemistry. *Geochim. Cosmochim. Acta.* 47, 785-794.

Volkman, J.K. and J.R. Maxwell. (1986) Acyclic isoprenoids as biological markers. In *Biological markers in the sedimentary record* (R.B. Johns, editor). pp. 1-42. Elsevier.

Volkman, J.K., D. A. Everitt and D. I. Allen (1986) Some analyses of lipid classes in marine organisms, sediments and seawater using thin-layer chromatography-flame ionisation detection. *J. Chromatogr.* 356, 147-162.

Volkman, J.K. (1987) Analysis of sediment and water samples from Bruny Island for petroleum hydrocarbons. *Unpublished report 87-HC2 to Conga Oil Pty. Ltd.*

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Figure 13c,d. Mass fragmentograms for m/z 205 showing distibution of C_{30}-C_{33} methyl hopanes in a sediment from North West Bay and a suspected seep sample form Bruny Island.

Figure 14a,b. Mass fragmentograms for m/z 217 and 218 showing distributions of C_{26}-C_{30} steranes and diasteranes in sample IB.

Figure 15a,b. Mass fragmentograms for m/z 217 and 218 showing distributions of C_{26}-C_{30} steranes and diasteranes in sample Q1.

Figure 16a,b. Mass fragmentograms for m/z 217 and 218 showing distributions of C_{26}-C_{30} steranes and diasteranes in sample Q2.

Figure 17a. Mass fragmentogram for m/z 218 showing distribution of C_{21}-C_{30} steranes in sample IB.

Figure 17b,c. Mass fragmentograms for m/z 218 showing distribution of C_{21}-C_{30} steranes in samples Q1 and Q2.

Figure 18a. Mass fragmentogram for m/z 259 showing distribution of rearranged steranes (diasteranes) in sample IB.

Figure 18b,c. Mass fragmentograms for m/z 259 showing distribution of rearranged steranes (diasteranes) in sample Q1 and Q2.

NOTES ON FIGURES

Figure 1. Iatroscan TLC-FID chromatograms give an indication of what lipid classes are in a sample and also their concentrations. The area under the peak is converted to a concentration value using calibration factors determined in earlier work (Volkman et al., 1986). The abbreviations are: POLARS: polar lipids, ST: sterols, HC: hydrocarbons.

Figures 2-4. These figures are capillary gas chromatograms obtained for hydrocarbon fractions that had been purified from other lipids by silic gel chromatography. Each peak represents a different compound (in a few cases two or more compounds may elute at the same retention time), and the area under the peak is directly proportional to the amount of that compound. Alkanes are given by $n-C_x$ where "x" is the number of carbon atoms.

Figure 5. This shows mass fragmentograms for m/z 113 obtained by GC-MS analysis of the total hydrocarbons. This ion is enhanced in the mass spectra of isoprenoid alkanes and thus enables the distribution of isoprenoid alkanes to be seen clearly in complex mixtures. This ion is also found in straight-chain alkanes and so n-alkanes also appear in these mass fragmentograms. Abbreviations are: Pr: pristane, Ph: phytane, TMTD: C_{16} isoprenoid alkane.

Figure 6. This shows mass fragmnetograms for m/z 57 which is the major fragment in the mass spectra of n-alkanes and m/z 83 which is the major fragment ion in alkyl cyclohexanes. m/z 57 also appears in the mass spectra of alkyl cyclohexanes, although it is a minor ion.

Figures 7-12. These show mass fragmentograms for m/z 191, 177 and 205 obtained by GC-MS analysis of the total hydrocarbons. All regular hopanes give very intense m/z 191 in their mass spectra so this ion is typically used to characterise hopane distributions. C_{29} hopanes also have a major fragment ion at m/z 177 and so are readily detected using this ion. Hopanes which lack at C-10 methyl group (called demethylated hopanes) also give a strong ion at m/z 177. C_{31} hopanes give a strong ion at m/z 205 and thus are readily distinguished by this ion. Hopanes with a methyl group in the A ring are readily distinguished by an intense ion at m/z 205 (corresponding to the same fragmentation that produces the m/z 191 ion in regular hopanes).

Mass fragmentograms for m/z 191 are given for two different time windows to make the distribution of C_{27} - C_{31} hopanes clearer. Note that there is a slight contibution to the background m/z 191 signal from column bleed. In extended hopanes (i.e. carbon numbers >C_{30}), two isomers called R and S can occur at position C-22 in the sidechain. The ratio of these two isomers changes in a systematic way with increasing maturity.

Figure 13. This shows the distribution of C_{30}-C_{33} methyl hopanes in the Q1 limestones and in sediments from D'Entrecasteaux Channel, North West Bay and Bruny Island. C_{31} hopanes (peaks 7 and 8) are also detected by the m/z 205 ion. Note the high abundance of the naturally-occurring 22R isomer of the C_{31} hopane in the sediment samples.

Figure 14-17. These show mass fragmentograms for m/z 217 and 218 over two different time windows. These ions are characteristic of regular steranes, but interferences can occur due to the presence of certain hopenes and other compounds. The ion m/z 218 is enhanced in isomers with α,β,β-stereochemistry, and in shorter chain steranes and so it is useful for identifying these compounds.

Figure 18. Diasteranes (steranes which have undergone a major rearrangement of the ring system) give small peaks in the m/z 217 mass fragmentogram so these are usually detected using mass fragmentograms of m/z 259 which is the base peak in the mass spectra of these compounds.

APPENDIX 7

220

775231

LEAMAN GEOPHYSICS

Survey Review, Specification, Reduction, Interpretation
Wide Experience Most Methods
Specialties:- Gravity, Magnetics, Seismic Methods

Registered Office:
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1987 GRAVITY SURVEY
PROJECT D'ENTRECASTEAUX

CONGA OIL PTY LTD

Following a preliminary assessment of available gravity data in southeast Tasmania which established the value of the gravity method as an aid to resolution of both dolerite and pre-Permian structuring additional data was acquired. This was essential outside the Cygnet and Catamaran areas since the existing TASGRAV data base was limited south and west of Margate.

The aim of the survey was provision of a greatly improved coverage and definition of the gravity field across the study area with some infill between the Huon River and the D'Entrecasteax Channel and on Bruny Island where the primary coverage was poor to fair. The initial budget set aside for the survey meant that only those sites readily accessed could be observed and no attempt was made to generate a regular or uniform station distribution. It was felt that if such further improvement was needed that the new survey and its interpretation would reveal those zones in which more data acquisition would be critical or advisable.
Consequently all available road access and some of the better vehicular tracks were utilised. Where any track presented problems (as by washout, fallen trees, locked gates and hard to find owners, etc) the traverse was terminated. No walking of stations was entertained.
Application of these principles has produced a considerably improved data base but there are still major gaps both within the developed areas and in the less accessible regions marginal to them. A second generation survey using helicopters and walking tracks could resolve any deficiencies. It is not yet known if this will be necessary.

Specification and supervision:
The survey was supervised and specified by Dr. D. Leaman of Leaman Geophysics, Hobart.
A tie station network was formed which was ultimately tied to BMR Isogal station 6091.0260 at Mount Nelson and cross linked to 6851.9354 at Snug.
A nominal station spacing of 1 to 2km was to be employed on all traverses.
Elevations were barometrically determined using base barometers, multiple roving barometers and spot control methods coupled with many repeat observations.

Contractor:
Solo Geophysics of Adelaide, Graham Rao observer.

Period of survey:
March 13 to April 24, 1987

Active licences during survey:
Only EL 29/84. Others pending and not advised.

Reductions:
Completed, checked and integrated with Tasgrav data by May 1, 1987 using a density of 2.67 t/cu m. Reductions by Leaman Geophysics.

Costs:
Survey: $24874
Reduction: 5180

$30054 or $35.36 per station

Tie station detail:

Base reference Mt Nelson	:	6091.0260	980389.56
Snug	:	6851.9354	980467.47
Huonville bridge NE	:	.9902	980459.03
Port Huon wharf	:	.9903	980475.94
Geeveston 4 ft bridge	:	.9904	980465.58
Dover library	:	.9905	980487.59
Strathblane hall	:	.9906	980490.82
Southport/Hastings jn	:	.9907	980492.42

Survey and compilation notes:
Some mismatches were noted between Tasgrav values and the new survey. These related mostly to old barometric surveys which lacked the benefit of new techniques and the good control now provided by Lands maps. Most previous work predates 1970 when basemaps were generally unavailable.
Other problem stations have been identified by reviewing patterns within the gravity field or the consistency of results upon re-occupation of sites. In most cases the Bouguer anomaly is within 0.5 mGal which indicates a long history of sound technique and reliable base networks.
Where possible, errors have been traced and the stations corrected. Very few have been deleted. In the case of parts of the Cygnet (6560), Hobart (6851) and Marathon (8050) surveys most errors relate to elevation but occasionally gravity difference or terrain correction errors were noted. Where height errors were recognised the precision on recovery is probably no better than 2 to 4 m. It must also be appreciated that no more than 30 stations were affected by any of these problems and only three were deleted from the data base.

The final recovery and compilation as presented at May 1, 1987 is satisfactory for the regional objectives of the D'Entrecasteaux project but any detailed replot of survey 6560 west of Cygnet should be reviewed with moderate caution and survey 8050 west of Lune River requires some additional confirmatory coverage. There may still be odd stations in these surveys which are suspect in elevation. The compilation provided uses a subset of the Marathon (8050) data and is thus partly filtered to provide a nominal 500 to 1000 m spacing. Very detailed coverage of local areas within the Hobart district have been similarly treated.

Several BMR traverses in Storm Bay have also been compiled. All stations listed on the BMR marine file have been reduced. Not all were assigned water depths on that file and estimates have been inserted using the supplied coordinates and Admiralty charts. These depths are likely to be accurate to within 5 m in most cases although some sites may be suspect by up to 10 m. These problems are, however, minor compared to the variation in results generated by the various surveys and traverses, and along some traverses. I suspect that not all corrections have been properly applied on ship and the plot is based only on those values which afford some consistency, both internal and between surveys. The entire Storm Bay result should be considered suspect until confirmed by new survey.

Precision:
Observed gravity: Stations reproducible to within 0.03 - 0.05 mGal after loop and drift correction.
Elevation: Generally better than 2 m; equivalent to an error of about 0.5 mGal in the Bouguer anomaly.
Position: Generally better than 100 m; equivalent to an error of no more than 0.1 mGal in the Bouguer anomaly.
Terrain correction: variable but estimated at 5% based on reproducibility; or about 0.05 to 0.15 mGal for most stations.

The RMS error is of the order of 0.6 mGal. Many stations will be much better than this but some could be of the order of 1 mGal. A general 2 mGal contour interval is justified. Some areas could be contoured at 1 mGal contour interval.

D.E.Leaman
May 1, 1987

LEAMAN GEOPHYSICS GRAVITY REDUCTION

D'ENTRECASTEAUX GRAVITY SURVEY - CONGA OIL

BASE VALUE	BASE NUMBER	METER	CAL DATE	SCALE	DENSITY	ELEV DATUM
980389.56	6091.0260	561	10187	1.0094	2.67	0.00

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.9902	503700.0	5235300.0	5.00	980459.03	980452.15	1.00	8.86
8700.9903	497950.0	5221600.0	2.00	980475.94	980463.26	0.40	13.48
8700.9904	493725.0	5221000.0	22.00	980465.58	980463.74	0.68	6.84
8700.9905	501000.0	5204200.0	25.00	980487.59	980477.37	0.48	15.62
8700.9906	497550.0	5201775.0	28.00	980490.82	980479.34	0.35	17.34
8700.9907	496140.0	5193080.0	56.00	980492.42	980486.39	0.44	17.48
8700.0001	499700.0	5202200.0	46.00	980486.13	980479.00	0.36	16.54
8700.0002	499575.0	5201150.0	3.00	980492.42	980479.85	1.24	14.40
8700.0003	500750.0	5201000.0	2.00	980492.10	980479.97	0.99	13.52
8700.0004	501925.0	5201225.0	3.00	980493.43	980479.79	0.62	14.85
8700.0005	502450.0	5200725.0	1.00	980493.87	980480.19	0.60	14.48
8700.0006	507550.0	5206750.0	1.50	980489.26	980475.30	0.16	14.41
8700.0007	496775.0	5200475.0	70.00	980482.34	980480.39	0.53	16.25
8700.0008	496550.0	5199350.0	77.00	980482.31	980481.31	0.44	16.59
8700.0009	496575.0	5198400.0	88.50	980481.31	980482.08	0.60	17.24
8700.0010	496250.0	5197050.0	122.00	980477.21	980483.17	0.58	18.61
8700.0011	496875.0	5195850.0	134.00	980475.04	980484.15	0.64	17.89
8700.0012	496300.0	5194500.0	167.50	980469.32	980485.24	0.45	17.48
8700.0013	495950.0	5200925.0	125.00	980471.33	980480.03	0.41	16.30
8700.0014	494775.0	5201175.0	169.00	980462.06	980479.83	0.49	15.97
8700.0015	493775.0	5200750.0	149.00	980465.41	980480.17	0.51	15.05
8700.0016	492975.0	5201125.0	149.00	980463.67	980479.86	0.47	13.58
8700.0017	492400.0	5200400.0	129.00	980467.65	980480.45	0.73	13.30
8700.0018	492925.0	5199550.0	109.00	980474.47	980481.14	0.83	15.60
8700.0019	492500.0	5198125.0	99.00	980476.77	980482.30	0.86	14.81
8700.0020	491120.0	5197500.0	103.00	980474.26	980482.80	0.72	12.43
8700.0021	493525.0	5200350.0	90.00	980478.54	980480.49	0.60	16.35
8700.0022	494425.0	5199950.0	89.00	980480.77	980480.82	0.33	17.79
8700.0023	494725.0	5199450.0	79.00	980483.55	980481.22	0.31	18.18
8700.0024	495675.0	5199200.0	89.00	980481.72	980481.43	0.36	18.16
8700.0025	496350.0	5200025.0	76.00	980483.01	980480.76	0.40	17.60
8700.0026	498300.0	5201050.0	15.00	980490.38	980479.93	1.00	14.40
8700.0027	497225.0	5199900.0	99.00	980477.71	980480.86	0.54	16.86
8700.0028	497975.0	5200050.0	149.00	980466.36	980480.74	0.90	15.83
8700.0029	497600.0	5198550.0	155.00	980469.47	980481.96	1.05	19.06
8700.0030	497425.0	5197600.0	217.00	980456.40	980482.73	0.80	17.16
8700.0031	498500.0	5197375.0	272.00	980445.07	980482.91	1.12	16.78
8700.0032	498400.0	5197825.0	335.00	980431.32	980482.54	1.29	15.96
8700.0033	498100.0	5196600.0	241.00	980451.30	980483.54	0.63	15.80
8700.0034	498700.0	5195825.0	272.00	980444.19	980484.17	0.77	14.29
8700.0035	499650.0	5196275.0	325.00	980435.48	980483.80	1.05	16.65
8700.0036	500900.0	5196600.0	349.00	980430.26	980483.54	1.50	16.87
8700.0037	500800.0	5197100.0	382.00	980423.09	980483.13	1.70	16.80
8700.0038	499375.0	5197050.0	500.00	980395.90	980483.17	7.70	18.78
8700.0039	501600.0	5195650.0	268.00	980445.19	980484.31	2.55	16.14
8700.0040	501600.0	5196700.0	295.00	980437.36	980483.46	2.40	14.33
8700.0041	497950.0	5194950.0	283.00	980444.32	980484.88	1.37	16.48
8700.0042	497675.0	5194400.0	261.00	980449.89	980485.32	1.07	16.98

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0043	491175.0	5196175.0	198.00	980452.81	980483.88	1.25	9.13
8700.0044	490150.0	5195800.0	192.00	980453.53	980484.18	1.60	8.71
8700.0045	489675.0	5196475.0	213.00	980452.39	980483.63	1.75	12.41
8700.0046	495225.0	5193200.0	76.00	980488.38	980486.30	0.37	17.40
8700.0047	494475.0	5192800.0	49.50	980492.78	980486.62	0.27	16.17
8700.0048	494125.0	5193200.0	2.50	980501.59	980486.30	0.33	16.12
8700.0049	494650.0	5191800.0	3.00	980501.58	980487.43	0.40	15.14
8700.0050	493425.0	5193200.0	10.00	980499.49	980486.29	0.30	15.46
8700.0051	493375.0	5192050.0	8.00	980501.27	980487.23	0.29	15.90
8700.0052	492500.0	5192750.0	27.00	980496.98	980486.66	0.27	15.90
8700.0053	490950.0	5192900.0	16.00	980489.25	980486.54	0.54	6.40
8700.0054	490000.0	5192650.0	18.00	980489.11	980486.74	0.65	6.56
8700.0055	489250.0	5193900.0	36.50	980486.68	980485.72	0.85	8.99
8700.0056	488675.0	5194425.0	51.00	980482.58	980485.30	0.90	8.21
8700.0057	488350.0	5194050.0	46.50	980482.46	980485.60	0.86	6.87
8700.0058	487875.0	5193350.0	38.00	980483.06	980486.17	0.90	5.27
8700.0059	488700.0	5192750.0	24.00	980487.85	980486.65	0.75	6.67
8700.0060	486900.0	5192875.0	52.00	980477.29	980486.55	1.20	2.16
8700.0061	487925.0	5195650.0	89.00	980473.05	980484.30	1.33	7.58
8700.0062	487100.0	5196525.0	140.00	980460.33	980483.59	1.95	6.23
8700.0063	489100.0	5195950.0	176.00	980458.75	980484.06	1.85	11.16
8700.0064	491800.0	5196675.0	130.00	980469.41	980483.47	0.95	12.46
8700.0065	491250.0	5195200.0	116.00	980471.51	980484.67	0.98	10.64
8700.0066	490250.0	5194125.0	47.00	980483.83	980485.54	0.80	8.33
8700.0067	497090.0	5192575.0	27.50	980499.52	980486.80	0.48	18.61
8700.0068	497675.0	5191975.0	12.00	980503.18	980487.29	0.30	18.55
8700.0069	497800.0	5191050.0	2.00	980505.75	980488.04	0.16	18.26
8700.0070	496850.0	5190450.0	2.00	980505.23	980488.53	0.24	17.33
8700.0071	496600.0	5189400.0	2.00	980506.63	980489.38	0.23	17.87
8700.0072	498450.0	5190625.0	2.00	980506.14	980488.39	0.19	18.34
8700.0073	499375.0	5191450.0	28.00	980501.59	980487.72	0.30	19.68
8700.0074	500900.0	5192150.0	1.00	980504.50	980487.15	0.59	18.14
8700.0075	498400.0	5192000.0	31.00	980500.40	980487.27	0.48	19.71
8700.0076	500200.0	5191750.0	41.00	980499.70	980487.47	0.41	20.71
8700.0077	501350.0	5193650.0	2.00	980501.36	980485.93	0.90	16.72
8700.0078	500600.0	5194100.0	108.00	980478.67	980485.57	0.88	15.23
8700.0079	498800.0	5193550.0	185.00	980466.60	980486.01	1.80	18.77
8700.0080	498200.0	5193400.0	242.00	980453.86	980486.13	1.89	17.21
8700.0081	497300.0	5193800.0	205.00	980460.92	980485.81	1.86	17.30
8700.0082	492200.0	5192225.0	6.00	980499.93	980487.08	0.31	14.33
8700.0083	492075.0	5191150.0	10.00	980498.04	980487.96	0.36	12.41
8700.0084	488900.0	5188300.0	57.00	980485.87	980490.27	2.13	8.94
8700.0085	488900.0	5189500.0	65.00	980483.05	980489.29	2.25	8.79
8700.0086	488700.0	5190100.0	76.00	980478.88	980488.80	2.15	7.18
8700.0087	488100.0	5190825.0	95.00	980473.64	980488.22	2.27	6.38
8700.0088	487300.0	5191550.0	62.00	980477.08	980487.63	2.65	4.30
8700.0089	486700.0	5192100.0	71.00	980474.96	980487.18	1.80	3.55
8700.0090	485700.0	5192300.0	140.00	980459.01	980487.02	2.45	1.98
8700.0091	487300.0	5191100.0	144.00	980461.49	980487.99	3.00	4.82
8700.0092	486600.0	5191400.0	170.00	980454.28	980487.75	3.75	3.72
8700.0093	485400.0	5191700.0	240.00	980437.53	980487.50	3.25	0.48
8700.0094	493300.0	5194650.0	61.00	980490.66	980485.12	0.88	18.42
8700.0095	493700.0	5196200.0	110.00	980479.58	980483.86	0.56	17.91
8700.0096	492500.0	5196500.0	60.00	980486.95	980483.62	0.54	15.67

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0097	492100.0	5194800.0	25.00	980494.02	980485.00	0.77	14.71
8700.0098	494600.0	5197425.0	99.00	980479.89	980482.87	0.38	16.88
8700.0099	494850.0	5198200.0	101.00	980479.61	980482.24	0.40	17.64
8700.0100	497500.0	5202350.0	3.00	980495.09	980478.87	0.35	17.16
8700.0101	496900.0	5202550.0	14.00	980491.04	980478.71	0.50	15.59
8700.0102	496400.0	5202600.0	36.00	980486.01	980478.67	0.70	15.12
8700.0103	495550.0	5202650.0	53.00	980482.11	980478.63	0.80	14.71
8700.0104	494950.0	5203000.0	72.00	980477.38	980478.35	1.30	14.49
8700.0105	494200.0	5203300.0	68.00	980477.19	980478.10	0.80	13.26
8700.0106	494350.0	5204750.0	82.00	980472.46	980476.92	0.70	12.37
8700.0107	493900.0	5205150.0	75.00	980472.32	980476.60	0.75	11.22
8700.0108	492800.0	5205850.0	67.00	980474.46	980476.03	0.72	12.33
8700.0109	491200.0	5206350.0	91.00	980465.01	980475.62	1.25	8.54
8700.0110	491400.0	5205350.0	116.00	980461.49	980476.44	0.90	8.77
8700.0111	490400.0	5204150.0	148.00	980455.31	980477.41	1.33	8.35
8700.0112	491250.0	5203850.0	98.00	980467.90	980477.65	0.80	10.32
8700.0113	491400.0	5202950.0	124.00	980461.33	980478.38	1.12	8.46
8700.0114	491550.0	5201750.0	160.00	980458.25	980479.36	0.61	10.97
8700.0115	493550.0	5202400.0	128.00	980467.33	980478.83	0.65	14.33
8700.0116	494600.0	5202250.0	81.00	980476.87	980478.95	0.45	14.30
8700.0117	495400.0	5201750.0	90.00	980475.46	980479.36	0.43	14.23
8700.0118	496350.0	5201300.0	60.00	980483.29	980479.72	0.48	15.85
8700.0119	498100.0	5203000.0	2.00	980493.58	980478.35	0.52	16.15
8700.0120	499800.0	5203100.0	18.00	980490.25	980478.27	0.40	15.92
8700.0121	500550.0	5203500.0	3.00	980493.08	980477.94	0.29	16.02
8700.0122	499075.0	5203750.0	46.00	980483.02	980477.74	0.50	14.83
8700.0123	498350.0	5204000.0	88.00	980473.69	980477.53	0.68	14.15
8700.0124	497950.0	5205150.0	151.00	980457.86	980476.60	0.60	11.56
8700.0125	497850.0	5206350.0	230.00	980440.61	980475.63	0.41	10.64
8700.0126	497500.0	5205400.0	195.00	980449.07	980476.40	0.80	11.83
8700.0127	497000.0	5204650.0	208.00	980447.01	980477.01	1.10	12.02
8700.0128	498600.0	5206850.0	276.00	980430.41	980475.22	0.35	9.83
8700.0129	497500.0	5207150.0	320.00	980420.02	980474.98	0.48	8.47
8700.0130	496500.0	5206650.0	261.00	980434.29	980475.38	0.52	10.76
8700.0131	496150.0	5207300.0	198.00	980445.83	980474.86	0.60	10.52
8700.0132	495900.0	5208100.0	112.00	980460.54	980474.21	0.75	9.11
8700.0133	494920.0	5207000.0	136.00	980457.97	980475.10	0.70	10.71
8700.0134	494200.0	5206450.0	138.00	980458.86	980475.55	0.72	11.18
8700.0135	492150.0	5207350.0	284.00	980427.67	980474.81	1.30	10.02
8700.0136	491350.0	5207750.0	305.00	980420.08	980474.49	1.70	7.29
8700.0137	490750.0	5208300.0	220.00	980433.27	980474.04	1.62	4.12
8700.0138	489850.0	5208300.0	145.00	980447.05	980474.04	1.30	2.84
8700.0139	488600.0	5208900.0	214.00	980430.43	980473.55	2.25	1.22
8700.0140	487900.0	5209950.0	320.00	980410.77	980472.70	1.48	2.49
8700.0141	487375.0	5210500.0	327.00	980407.71	980472.25	1.85	1.63
8700.0142	486775.0	5210950.0	351.00	980400.57	980471.89	2.39	0.12
8700.0143	485900.0	5212425.0	460.00	980374.81	980470.69	1.90	-3.49
8700.0144	486200.0	5211675.0	411.00	980388.72	980471.30	2.60	0.87
8700.0145	486325.0	5210650.0	382.00	980395.98	980472.13	1.96	0.95
8700.0146	485375.0	5211275.0	447.00	980380.22	980471.62	2.00	-1.47
8700.0147	490150.0	5207700.0	156.00	980445.67	980474.53	1.08	2.91
8700.0148	490600.0	5207200.0	116.00	980454.88	980474.93	1.15	3.91
8700.0149	490700.0	5206500.0	101.00	980459.15	980475.50	1.30	4.81
8700.0150	491900.0	5206150.0	81.00	980470.24	980475.79	0.70	11.09

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0151	500500.0	5205250.0	34.00	980482.34	980476.52	1.20	13.71
8700.0152	500850.0	5206150.0	42.00	980480.28	980475.79	1.35	14.10
8700.0153	500750.0	5207000.0	53.00	980477.28	980475.10	1.08	13.68
8700.0154	500650.0	5208050.0	61.00	980472.37	980474.25	1.45	11.57
8700.0155	500700.0	5208900.0	86.00	980467.19	980473.56	1.71	12.26
8700.0156	500600.0	5209900.0	127.00	980454.62	980472.75	1.12	7.97
8700.0157	499850.0	5210675.0	181.00	980443.29	980472.12	0.54	7.31
8700.0158	499450.0	5210950.0	175.00	980444.02	980471.90	0.58	7.12
8700.0159	499125.0	5212650.0	60.00	980464.77	980470.52	0.48	6.53
8700.0160	498900.0	5213575.0	40.00	980468.84	980469.77	0.72	7.66
8700.0161	499050.0	5214775.0	6.00	980476.66	980468.79	0.54	9.59
8700.0162	499750.0	5214650.0	37.00	980471.13	980468.90	0.62	10.13
8700.0163	500150.0	5214450.0	33.00	980472.39	980469.06	0.70	10.52
8700.0164	501100.0	5213700.0	28.00	980474.16	980469.67	0.66	10.66
8700.0165	501750.0	5213700.0	20.00	980476.31	980469.67	0.82	11.39
8700.0166	502000.0	5213150.0	28.00	980474.69	980470.11	1.00	11.09
8700.0167	501100.0	5212600.0	79.00	980463.10	980470.56	0.80	8.88
8700.0168	500600.0	5212250.0	127.00	980454.05	980470.84	0.55	8.74
8700.0169	500800.0	5210750.0	225.00	980434.56	980472.06	0.77	7.53
8700.0170	501700.0	5203650.0	2.00	980492.44	980477.82	0.28	15.29
8700.0171	502500.0	5204100.0	7.00	980490.88	980477.45	0.48	15.29
8700.0172	503500.0	5204350.0	3.00	980492.11	980477.25	0.37	15.82
8700.0173	503650.0	5205600.0	48.00	980479.72	980476.24	0.97	13.89
8700.0174	503600.0	5206400.0	78.00	980473.17	980475.59	0.92	13.84
8700.0175	502950.0	5206450.0	133.00	980461.56	980475.55	1.10	13.27
8700.0176	504250.0	5203800.0	1.00	980492.07	980477.70	0.31	14.88
8700.0177	505200.0	5204400.0	32.00	980485.99	980477.21	0.40	15.47
8700.0178	505800.0	5204800.0	85.00	980472.09	980476.88	0.90	12.82
8700.0179	506250.0	5205800.0	39.00	980480.80	980476.07	0.73	13.13
8700.0180	505950.0	5206700.0	75.00	980474.74	980475.34	0.66	14.81
8700.0181	505450.0	5207400.0	78.00	980473.34	980474.78	0.36	14.27
8700.0182	505200.0	5206550.0	118.00	980465.86	980475.46	0.48	14.09
8700.0183	506650.0	5206950.0	4.00	980487.68	980475.14	0.33	13.66
8700.0184	507200.0	5207700.0	57.00	980477.14	980474.53	0.55	14.38
8700.0185	507100.0	5208100.0	1.50	980487.93	980474.21	0.49	14.50
8700.0186	506300.0	5208400.0	80.00	980471.69	980473.96	0.77	14.24
8700.0187	505600.0	5208850.0	85.00	980470.38	980473.60	0.64	14.14
8700.0188	505700.0	5208200.0	139.00	980461.08	980474.13	0.67	14.96
8700.0189	504900.0	5208200.0	108.00	980467.05	980474.13	0.41	14.58
8700.0190	504150.0	5208200.0	171.00	980453.47	980474.13	0.36	13.34
8700.0191	503650.0	5208150.0	194.00	980448.25	980474.17	0.41	12.65
8700.0192	505600.0	5209500.0	5.00	980486.42	980473.07	1.12	15.45
8700.0193	505250.0	5210250.0	8.00	980485.79	980472.46	0.88	15.78
8700.0194	504400.0	5211150.0	38.00	980478.93	980471.73	1.15	15.82
8700.0195	504150.0	5211600.0	2.00	980483.88	980471.37	0.87	13.77
8700.0196	503600.0	5211950.0	2.00	980482.43	980471.09	0.81	12.55
8700.0197	502850.0	5211950.0	1.00	980480.36	980471.09	1.28	10.76
8700.0198	502300.0	5212700.0	36.00	980473.56	980470.48	1.20	11.37
8700.0199	503100.0	5211150.0	95.00	980462.24	980471.73	0.75	9.94
8700.0200	502600.0	5210800.0	138.00	980453.41	980472.02	0.68	9.22
8700.0201	501800.0	5211200.0	124.00	980455.68	980471.69	0.45	8.82
8700.0202	501100.0	5211700.0	139.00	980452.14	980471.29	0.50	8.69
8700.0203	499050.0	5205200.0	119.00	980463.74	980476.56	0.75	11.34
8700.0204	499200.0	5208250.0	288.00	980423.48	980474.09	0.66	6.70

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0205	498650.0	5209350.0	286.00	980425.03	980473.19	0.42	8.51
8700.0206	497750.0	5209850.0	285.00	980425.60	980472.79	0.40	9.27
8700.0207	497675.0	5210100.0	284.00	980425.18	980472.59	0.48	8.94
8700.0208	498225.0	5210425.0	271.00	980427.82	980472.32	0.34	9.14
8700.0209	499100.0	5210325.0	230.00	980435.94	980472.40	0.36	9.14
8700.0210	489200.0	5207200.0	268.00	980422.85	980474.93	1.70	2.33
8700.0211	488950.0	5207900.0	351.00	980405.58	980474.36	1.85	2.11
8700.0212	488320.0	5207600.0	372.00	980404.21	980474.61	1.13	3.90
8700.0213	487600.0	5207100.0	334.00	980409.06	980475.01	1.25	1.00
8700.0214	487450.0	5206400.0	375.00	980401.57	980475.58	1.50	1.26
8700.0215	491950.0	5208450.0	411.00	980400.56	980473.92	0.95	8.43
8700.0216	492600.0	5209450.0	364.00	980410.35	980473.11	0.83	9.67
8700.0217	493391.0	5210475.0	384.00	980403.12	980472.28	0.45	6.82
8700.0218	494800.0	5210100.0	223.00	980435.85	980472.59	0.68	7.81
8700.0219	495250.0	5209700.0	121.00	980456.46	980472.91	0.52	7.87
8700.0220	495150.0	5208600.0	118.00	980459.13	980473.80	0.60	9.14
8700.0221	496950.0	5208150.0	208.00	980439.62	980474.17	0.79	7.15
8700.0222	497700.0	5208900.0	248.00	980434.43	980473.56	0.84	10.49
8700.0223	496400.0	5209100.0	270.00	980428.09	980473.40	0.73	8.53
8700.0224	496800.0	5210000.0	263.00	980427.64	980472.67	0.55	7.26
8700.0225	497225.0	5210800.0	231.00	980434.69	980472.02	0.67	8.78
8700.0226	496425.0	5211650.0	195.00	980441.43	980471.33	0.88	9.34
8700.0227	496250.0	5210300.0	155.00	980450.42	980472.42	0.65	9.13
8700.0228	492675.0	5210725.0	448.00	980390.70	980472.08	0.40	7.15
8700.0229	491925.0	5211175.0	513.00	980374.68	980471.71	0.60	4.48
8700.0230	491650.0	5212000.0	509.00	980375.48	980471.04	0.51	5.07
8700.0231	492275.0	5213075.0	469.00	980383.34	980470.17	0.50	5.92
8700.0232	492675.0	5214325.0	380.00	980396.52	980469.16	0.65	2.76
8700.0233	492650.0	5215175.0	360.00	980401.70	980468.47	0.62	4.67
8700.0234	492600.0	5216350.0	307.00	980411.20	980467.51	0.70	4.77
8700.0235	493500.0	5215725.0	196.00	980431.55	980468.02	0.90	2.98
8700.0236	493825.0	5220450.0	28.00	980464.70	980464.19	0.50	6.52
8700.0237	493700.0	5219900.0	31.00	980463.99	980464.64	0.54	5.99
8700.0238	492350.0	5219050.0	54.00	980459.60	980465.32	0.57	5.47
8700.0239	491300.0	5218550.0	150.00	980442.24	980465.73	0.55	6.57
8700.0240	490100.0	5218350.0	106.00	980447.80	980465.89	1.27	4.03
8700.0241	489300.0	5219100.0	142.00	980440.44	980465.28	1.42	4.52
8700.0242	494500.0	5218200.0	73.00	980456.49	980466.02	0.62	5.46
8700.0243	494900.0	5217500.0	98.00	980452.72	980466.58	0.42	5.83
8700.0244	495550.0	5217050.0	123.00	980448.48	980466.95	0.45	6.17
8700.0245	496400.0	5217050.0	91.00	980456.21	980466.95	0.70	7.86
8700.0246	497000.0	5217800.0	2.50	980473.39	980466.34	0.75	8.29
8700.0247	497300.0	5216200.0	20.00	980470.73	980467.64	0.60	7.62
8700.0248	497000.0	5215250.0	81.00	980458.80	980468.41	1.01	7.34
8700.0249	498050.0	5215750.0	31.00	980470.36	980468.00	0.80	9.26
8700.0250	498600.0	5215600.0	50.00	980469.10	980468.13	0.75	11.56
8700.0251	494950.0	5216300.0	88.00	980453.97	980467.56	0.76	4.48
8700.0252	494050.0	5215450.0	141.00	980442.64	980468.25	0.80	2.93
8700.0253	467800.0	5175550.0	1.00	980524.28	980500.56	0.48	24.40
8700.0254	461600.0	5175450.0	100.00	980499.14	980500.61	0.90	19.10
8700.0255	466400.0	5179100.0	1.00	980515.28	980497.67	0.50	18.30
8700.0256	469250.0	5176450.0	1.00	980520.93	980499.83	0.59	21.88
8700.0257	471750.0	5174350.0	1.00	980521.59	980501.55	0.95	21.19
8700.0258	473700.0	5173000.0	1.00	980524.11	980502.65	1.81	23.47

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0259	476300.0	5172800.0	429.00	980438.04	980502.82	1.08	20.69
8700.0260	482600.0	5172250.0	1.00	980528.65	980503.28	0.38	25.95
8700.0261	485000.0	5171600.0	1.00	980531.13	980503.81	0.26	27.77
8700.0262	490800.0	5179000.0	10.00	980512.11	980497.82	0.16	16.42
8700.0263	490900.0	5179050.0	1.00	980514.19	980497.78	0.17	16.78
8700.0264	484900.0	5180200.0	780.00	980342.27	980496.83	21.10	19.96
8700.0268	466250.0	5179450.0	1.00	980514.07	980497.39	0.52	17.40
8700.0269	465650.0	5180900.0	1.00	980510.54	980496.21	0.86	15.38
8700.0270	465500.0	5183000.0	1.00	980503.47	980494.50	1.45	10.61
8700.0271	464700.0	5186900.0	2.00	980494.18	980491.33	1.72	4.96
8700.0272	464100.0	5192000.0	10.00	980481.87	980487.19	1.80	-1.56
8700.0273	466050.0	5196400.0	70.00	980461.73	980483.63	2.95	-5.18
8700.0276	502550.0	5203000.0	1.00	980493.68	980478.35	0.27	15.80
8700.0277	503200.0	5202250.0	1.00	980494.76	980478.95	0.24	16.24
8700.0278	503250.0	5201350.0	1.00	980496.94	980479.68	0.31	17.76
8700.0279	505550.0	5203050.0	1.00	980492.16	980478.30	0.49	14.55
8700.0280	508000.0	5195800.0	1.00	980502.23	980484.18	0.15	18.39
8700.0281	507750.0	5194850.0	1.00	980503.30	980484.95	0.17	18.71
8700.0282	507950.0	5193600.0	1.00	980505.56	980485.97	0.14	19.93
8700.0283	508300.0	5193250.0	1.00	980504.82	980486.25	0.17	18.94
8700.0284	509100.0	5190400.0	1.00	980509.33	980488.56	0.44	21.41
8700.0285	511200.0	5189900.0	1.00	980508.91	980488.97	0.46	20.60
8700.0286	512650.0	5188000.0	1.00	980512.07	980490.51	0.16	21.92
8700.0287	514450.0	5189500.0	1.00	980513.40	980489.29	0.53	24.84
8700.0288	514250.0	5190500.0	1.00	980513.32	980488.48	0.25	25.29
8700.0289	513800.0	5193700.0	1.00	980509.57	980485.88	0.16	24.04
8700.0290	511250.0	5206450.0	1.00	980494.78	980475.54	0.19	19.63
8700.0291	510400.0	5210600.0	1.00	980487.42	980472.17	0.17	15.61
8700.0292	511800.0	5207300.0	1.00	980493.75	980474.85	0.20	19.30
8700.0293	514450.0	5207050.0	1.00	980490.39	980475.05	0.21	15.75
8700.0295	499250.0	5177750.0	1.00	980522.82	980498.84	0.15	24.33
8700.0296	499650.0	5179600.0	1.00	980520.04	980497.33	0.15	23.06
8700.0297	499800.0	5180800.0	1.00	980517.56	980496.36	0.15	21.55
8700.0298	500500.0	5186200.0	1.00	980511.33	980491.98	0.12	19.67
8700.0299	510600.0	5188450.0	2.00	980511.03	980490.15	0.33	21.61
8700.0300	514350.0	5188450.0	1.00	980513.76	980490.14	0.48	24.29
8700.0301	513850.0	5192250.0	1.00	980511.71	980487.06	0.17	25.02
8700.0302	514800.0	5192600.0	1.00	980508.52	980486.77	0.27	22.21
8700.0303	514000.0	5194400.0	1.00	980509.03	980485.31	0.21	24.13
8700.0304	515350.0	5199950.0	1.00	980499.57	980480.81	0.15	19.11
8700.0305	517450.0	5203750.0	1.00	980502.10	980477.72	0.22	24.79
8700.0306	518350.0	5203250.0	1.00	980502.55	980478.12	0.24	24.86
8700.0307	521900.0	5208000.0	1.00	980494.68	980474.26	0.55	21.16
8700.0308	523000.0	5209200.0	1.00	980494.22	980473.29	0.65	21.79
8700.0309	523300.0	5211000.0	1.00	980495.43	980471.82	0.23	24.04
8700.0310	523650.0	5212200.0	4.00	980495.03	980470.85	0.20	25.17
8700.0311	523450.0	5216850.0	1.00	980490.29	980467.08	0.10	23.50
8700.0312	523500.0	5217350.0	1.00	980489.98	980466.67	0.10	23.61
8700.0313	523750.0	5219750.0	1.00	980487.97	980464.73	0.17	23.61
8700.0314	492200.0	5217550.0	282.00	980416.41	980466.54	0.55	5.89
8700.0315	492600.0	5221175.0	45.00	980460.66	980463.60	0.65	6.56
8700.0316	491725.0	5221250.0	78.00	980455.10	980463.54	0.60	7.50
8700.0317	491125.0	5221325.0	90.00	980453.16	980463.48	0.55	7.94
8700.0318	490000.0	5221950.0	152.00	980440.87	980462.97	0.77	8.57

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8700.0319	488750.0	5222125.0	232.00	980425.26	980462.83	0.48	8.55
8700.0320	487950.0	5222500.0	248.00	980421.57	980462.52	0.43	8.26
8700.0321	486650.0	5222125.0	263.00	980417.42	980462.82	0.49	6.82
8700.0322	486550.0	5221625.0	299.00	980411.29	980463.23	0.67	7.55
8700.0323	485375.0	5221950.0	252.00	980419.44	980462.96	0.74	6.78
8700.0324	484575.0	5220975.0	178.00	980432.79	980463.75	1.30	5.35
8700.0325	483925.0	5221750.0	159.00	980436.11	980463.12	0.82	5.09
8700.0326	483050.0	5222225.0	151.00	980436.74	980462.74	1.13	4.84
8700.0327	482925.0	5223300.0	145.00	980437.09	980461.86	1.20	4.95
8700.0328	483000.0	5224100.0	163.00	980433.21	980461.21	1.07	5.12
8700.0329	482450.0	5225625.0	118.00	980441.44	980459.98	1.08	5.76
8700.0330	481750.0	5226550.0	230.00	980416.21	980459.23	1.55	3.77
8700.0331	480875.0	5227225.0	342.00	980393.54	980458.68	0.77	2.90
8700.0332	480975.0	5227675.0	369.00	980386.90	980458.31	0.80	1.97
8700.0333	481375.0	5228500.0	462.00	980365.91	980457.64	1.48	0.62
8700.0334	480650.0	5226550.0	345.00	980394.12	980459.22	0.88	3.64
8700.0335	479800.0	5225700.0	338.00	980393.79	980459.91	0.87	1.23
8700.0336	479600.0	5224800.0	382.00	980384.55	980460.64	2.15	1.20
8700.0337	480200.0	5223925.0	365.00	980388.50	980461.35	2.60	1.55
8700.0338	480750.0	5223200.0	325.00	980394.76	980461.94	1.81	-1.44
8700.0339	481550.0	5222600.0	305.00	980403.99	980462.43	1.00	2.56
8700.0340	480750.0	5220500.0	465.00	980366.68	980464.13	3.99	-2.00
8700.0341	481650.0	5221650.0	469.00	980364.60	980463.20	4.12	-2.23
8700.0342	482525.0	5220850.0	375.00	980385.84	980463.85	2.43	-1.82
8700.0343	483350.0	5220775.0	241.00	980428.65	980463.91	1.15	13.30
8700.0344	482350.0	5219675.0	311.00	980401.68	980464.80	2.01	0.06
8700.0345	481600.0	5220275.0	394.00	980385.90	980464.31	2.73	1.81
8700.0346	481500.0	5218800.0	443.00	980374.75	980465.51	2.13	-1.49
8700.0347	481300.0	5219850.0	352.00	980392.58	980464.66	2.32	-0.52
8700.0348	482400.0	5218750.0	382.00	980387.44	980465.55	3.21	0.24
8700.0349	482600.0	5217150.0	491.00	980368.09	980466.85	2.13	-0.05
8700.0350	482850.0	5216500.0	527.00	980362.98	980467.38	1.40	0.67
8700.0351	481950.0	5217150.0	574.00	980347.20	980466.85	2.56	-4.19
8700.0352	480950.0	5217200.0	774.00	980307.92	980466.81	3.82	-2.82
8700.0353	481000.0	5216400.0	794.00	980304.19	980467.45	2.97	-4.12
8700.0354	481150.0	5215800.0	790.00	980305.62	980467.94	3.27	-3.66
8700.0355	481000.0	5215150.0	835.00	980295.56	980468.47	3.06	-5.61
8700.0356	486650.0	5219900.0	435.00	980382.73	980464.63	3.96	7.62
8700.0357	487100.0	5218550.0	544.00	980360.03	980465.72	1.95	3.26
8700.0358	486550.0	5219300.0	590.00	980351.04	980465.11	1.90	3.88
8700.0359	485900.0	5218950.0	540.00	980359.41	980465.40	2.20	2.43
8700.0360	485500.0	5217850.0	567.00	980356.38	980466.29	2.95	4.57
8700.0361	485450.0	5216900.0	595.00	980349.28	980467.06	1.76	1.01
8700.0362	494100.0	5220825.0	15.00	980467.87	980463.89	0.80	7.73
8700.0363	495100.0	5220600.0	7.00	980469.17	980464.07	0.82	7.30
8700.0364	496700.0	5221725.0	7.00	980472.71	980463.16	1.01	11.94
8700.0365	498125.0	5222475.0	11.00	980475.07	980462.55	0.91	15.59
8700.0366	497575.0	5223500.0	4.00	980474.14	980461.72	1.30	14.51
8700.0367	498000.0	5224300.0	5.00	980473.64	980461.07	1.25	14.81
8700.0368	499050.0	5224725.0	18.00	980471.37	980460.72	1.15	15.34
8700.0369	499400.0	5226300.0	3.00	980473.44	980459.45	1.30	15.88
8700.0370	498400.0	5226600.0	124.00	980451.38	980459.20	0.75	17.31
8700.0371	497675.0	5225950.0	169.00	980442.86	980459.73	0.71	17.08
8700.0372	496675.0	5226375.0	217.00	980431.95	980459.39	0.60	15.85

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0373	495500.0	5226800.0	291.00	980415.20	980459.04	0.81	14.21
8700.0374	499875.0	5226880.0	8.00	980473.14	980458.98	1.52	17.25
8700.0375	498950.0	5226900.0	105.00	980454.35	980458.96	1.10	17.14
8700.0376	497875.0	5227325.0	116.00	980450.01	980458.62	1.13	15.34
8700.0377	497900.0	5227925.0	265.00	980419.51	980458.13	1.30	14.80
8700.0378	496125.0	5222700.0	112.00	980452.39	980462.37	2.27	14.33
8700.0379	495575.0	5223025.0	199.00	980434.01	980462.10	1.55	12.60
8700.0380	494750.0	5222025.0	202.00	980432.67	980462.91	1.43	10.92
8700.0381	495800.0	5220800.0	3.50	980472.37	980463.91	1.27	10.42
8700.0382	492050.0	5215800.0	292.00	980412.47	980467.96	1.65	3.60
8700.0383	492050.0	5215075.0	267.00	980417.74	980468.55	1.62	3.33
8700.0384	491650.0	5215500.0	250.00	980419.45	980468.20	1.52	1.94
8700.0385	490500.0	5216350.0	214.00	980425.12	980467.51	2.07	1.77
8700.0386	490000.0	5217100.0	190.00	980429.72	980466.90	2.25	2.44
8700.0387	488900.0	5216600.0	325.00	980401.85	980467.31	2.13	0.61
8700.0388	488950.0	5216850.0	279.00	980411.19	980467.10	2.67	1.64
8700.0389	489600.0	5216850.0	219.00	980423.69	980467.10	2.10	1.76
8700.0390	491850.0	5214100.0	391.00	980393.88	980469.34	0.90	2.35
8700.0391	491500.0	5214650.0	355.00	980401.13	980468.89	1.12	3.18
8700.0392	490900.0	5215000.0	360.00	980398.19	980468.61	1.18	1.58
8700.0393	490300.0	5215450.0	335.00	980402.26	980468.24	1.24	1.15
8700.0394	490650.0	5212500.0	543.00	980366.03	980470.63	1.60	3.80
8700.0395	489725.0	5213600.0	555.00	980362.22	980469.74	1.50	3.14
8700.0396	488800.0	5213700.0	543.00	980365.80	980469.66	1.45	4.40
8700.0397	488075.0	5213000.0	475.00	980378.15	980470.23	1.55	2.91
8700.0398	487700.0	5212050.0	431.00	980388.95	980471.00	0.60	3.34
8700.0399	488650.0	5212500.0	404.00	980395.97	980470.63	0.55	5.35
8700.0400	489300.0	5212400.0	400.00	980397.36	980470.71	0.70	6.03
8700.0401	488100.0	5210800.0	398.00	980398.49	980472.01	0.65	5.42
8700.0402	488600.0	5209700.0	377.00	980403.19	980472.90	0.85	5.29
8700.0403	493200.0	5222500.0	46.00	980458.99	980462.53	1.35	6.86
8700.0404	492375.0	5222825.0	90.00	980451.41	980462.26	0.73	7.58
8700.0405	491675.0	5223175.0	141.00	980441.99	980461.98	0.60	8.34
8700.0406	490900.0	5223475.0	181.00	980432.90	980461.73	0.77	7.54
8700.0407	492975.0	5223525.0	70.00	980454.66	980461.70	1.08	7.81
8700.0408	492700.0	5224275.0	92.00	980450.13	980461.09	1.40	8.54
8700.0409	479350.0	5227450.0	258.00	980405.04	980458.49	1.93	-0.77
8700.0410	479700.0	5228300.0	226.00	980410.61	980457.80	2.05	-0.69
8700.0411	478250.0	5227450.0	86.00	980436.26	980458.49	1.11	-4.20
8700.0412	478150.0	5228000.0	61.00	980441.94	980458.04	0.94	-3.16
8700.0413	477600.0	5228750.0	59.00	980441.02	980457.43	0.75	-4.06
8700.0414	477250.0	5229250.0	110.00	980430.42	980457.03	1.20	-3.77
8700.0415	475900.0	5229250.0	193.00	980411.61	980457.02	1.76	-5.69
8700.0416	477200.0	5230200.0	252.00	980403.01	980456.25	2.80	-0.88
8700.0417	476000.0	5230900.0	336.00	980385.22	980455.68	3.63	-0.74
8700.0418	478150.0	5229900.0	79.00	980438.92	980456.50	1.60	-0.44
8700.0419	477800.0	5232100.0	130.00	980425.97	980454.72	2.53	-0.65
8700.0420	479300.0	5228900.0	91.00	980436.39	980457.31	2.61	-0.42
8700.0421	479600.0	5229800.0	65.00	980441.27	980456.58	2.80	0.27
8700.0422	479800.0	5231100.0	106.00	980433.89	980455.53	1.27	0.48
8700.0423	479825.0	5231600.0	85.00	980441.20	980455.13	1.25	4.04
8700.0424	480750.0	5231875.0	90.00	980440.97	980454.91	1.49	5.26
8700.0425	481775.0	5231450.0	126.00	980435.58	980455.25	2.19	7.30
8700.0426	482000.0	5230350.0	240.00	980413.90	980456.14	2.25	7.21

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0427	482850.0	5230625.0	298.00	980401.58	980455.92	2.93	7.21
8700.0428	483350.0	5231400.0	260.00	980408.19	980455.30	2.80	6.84
8700.0429	483875.0	5230650.0	194.00	980423.20	980455.90	2.90	8.36
8700.0430	484375.0	5229775.0	120.00	980437.60	980456.62	2.00	6.59
8700.0431	484875.0	5231250.0	70.00	980447.91	980455.42	0.87	7.13
8700.0432	485450.0	5231550.0	48.00	980452.84	980455.18	0.80	7.90
8700.0433	484000.0	5229250.0	110.00	980440.65	980457.04	2.08	7.32
8700.0434	483800.0	5228050.0	113.00	980441.08	980458.01	2.04	7.33
8700.0435	483375.0	5227325.0	175.00	980428.40	980458.60	2.37	6.59
8700.0436	483200.0	5228650.0	253.00	980412.28	980457.53	2.65	7.17
8700.0437	483500.0	5226425.0	148.00	980436.19	980459.33	2.30	8.28
8700.0438	487200.0	5223150.0	244.00	980420.90	980461.99	0.55	7.45
8700.0439	486900.0	5224300.0	227.00	980423.26	980461.06	0.47	7.33
8700.0440	486200.0	5224600.0	232.00	980422.56	980460.81	0.59	7.97
8700.0441	485400.0	5225400.0	264.00	980415.91	980460.16	0.95	8.62
8700.0442	485650.0	5226050.0	243.00	980417.94	980459.64	0.92	7.02
8700.0443	485475.0	5226700.0	161.00	980433.66	980459.11	0.64	6.86
8700.0444	488350.0	5224150.0	308.00	980407.75	980461.18	0.52	7.67
8700.0445	486950.0	5225150.0	228.00	980423.29	980460.37	0.40	8.17
8700.0446	487900.0	5225450.0	232.00	980423.55	980460.13	0.50	9.55
8700.0447	488600.0	5226400.0	267.00	980415.18	980459.36	0.91	9.25
8700.0448	488300.0	5227200.0	260.00	980415.62	980458.71	0.73	8.78
8700.0449	487450.0	5227200.0	200.00	980427.13	980458.71	0.80	8.56
8700.0450	486750.0	5227175.0	172.00	980432.18	980458.73	0.85	8.13

LEAMAN GEOPHYSICS   GRAVITY REDUCTION

D'ENTRECASTEAUX GRAVITY SURVEY - CONGA OIL

BASE VALUE	BASE NUMBER	METER	CAL DATE	SCALE	DENSITY	ELEV DATUM
980389.56	6091.0260	561	10187	1.0094	2.67	0.00

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0451	486750.0	5228150.0	138.00	980436.62	980457.94	1.15	6.98
8700.0452	489350.0	5227250.0	298.00	980408.71	980458.67	1.60	10.25
8700.0453	490100.0	5228000.0	356.00	980397.79	980458.06	1.75	11.50
8700.0454	490150.0	5229000.0	434.00	980381.37	980457.25	1.80	11.29
8700.0455	489850.0	5230200.0	433.00	980376.98	980456.28	1.17	7.04
8700.0456	489500.0	5230800.0	391.00	980385.52	980455.79	1.20	7.84
8700.0457	488600.0	5231500.0	351.00	980392.94	980455.22	1.67	8.43
8700.0458	488300.0	5231950.0	345.00	980393.84	980454.86	1.72	8.56
8700.0459	490600.0	5229800.0	517.00	980361.09	980456.60	1.15	7.32
8700.0460	491200.0	5230350.0	462.00	980373.19	980456.16	0.67	8.57
8700.0461	491450.0	5231000.0	476.00	980368.19	980455.63	0.71	6.90
8700.0462	492100.0	5231500.0	509.00	980361.04	980455.23	0.61	6.55
8700.0463	491800.0	5232050.0	501.00	980361.78	980454.78	1.18	6.73
8700.0464	488600.0	5224800.0	272.00	980415.06	980460.66	0.57	8.47
8700.0465	494400.0	5238100.0	37.00	980450.06	980449.88	1.96	9.42
8700.0466	494050.0	5237550.0	83.00	980441.88	980450.32	2.20	10.08
8700.0467	493100.0	5236900.0	227.00	980414.89	980450.85	1.43	10.12
8700.0468	492350.0	5236500.0	268.00	980408.33	980451.17	1.34	11.22
8700.0469	492250.0	5236300.0	264.00	980409.23	980451.34	1.23	11.06
8700.0470	491700.0	5235800.0	268.00	980407.90	980451.74	0.62	9.50
8700.0471	491750.0	5235200.0	272.00	980408.02	980452.23	0.55	9.85
8700.0472	490900.0	5234550.0	360.00	980391.37	980452.75	0.95	10.38
8700.0473	490800.0	5233300.0	450.00	980371.92	980453.77	0.77	7.43
8700.0474	491650.0	5232650.0	497.00	980362.37	980454.29	0.80	6.63
8700.0475	491400.0	5234700.0	292.00	980404.17	980452.63	0.82	9.79
8700.0476	492750.0	5235650.0	269.00	980407.69	980451.86	0.95	9.69
8700.0477	492600.0	5234000.0	316.00	980399.11	980453.20	0.80	8.87
8700.0478	496800.0	5236000.0	32.00	980452.61	980451.58	1.75	9.07
8700.0479	488100.0	5236300.0	53.00	980447.76	980451.33	1.55	8.41
8700.0480	487900.0	5235450.0	33.00	980451.16	980452.02	1.33	6.96
8700.0481	487000.0	5235100.0	37.00	980452.68	980452.30	1.40	9.05
8700.0482	485850.0	5234250.0	76.00	980448.52	980452.99	1.20	11.68
8700.0483	485400.0	5233350.0	46.00	980453.07	980453.72	0.95	9.35
8700.0484	485250.0	5232450.0	55.00	980451.84	980454.45	0.75	8.96
8700.0485	485100.0	5232000.0	56.00	980451.86	980454.81	0.72	8.78
8700.0486	488900.0	5241000.0	45.00	980445.07	980447.52	2.02	8.42
8700.0487	486000.0	5239000.0	45.00	980450.52	980449.14	1.02	11.25
8700.0488	485250.0	5238750.0	82.00	980442.99	980449.34	1.07	10.85
8700.0489	484500.0	5237550.0	178.00	980424.07	980450.31	1.33	10.10
8700.0490	484600.0	5236800.0	161.00	980426.93	980450.92	1.14	8.82
8700.0491	484650.0	5235950.0	159.00	980427.18	980451.61	1.00	7.65
8700.0492	484700.0	5235100.0	115.00	980437.39	980452.30	0.92	8.64
8700.0493	484700.0	5234500.0	110.00	980438.51	980452.79	0.85	8.21
8700.0494	484150.0	5233800.0	53.00	980451.45	980453.35	0.94	9.46
8700.0495	483900.0	5232950.0	41.00	980455.37	980454.04	0.75	10.15
8700.0496	483000.0	5232550.0	43.00	980452.59	980454.36	0.90	7.57
8700.0497	481950.0	5232750.0	45.00	980452.50	980454.20	1.12	8.27
8700.0498	481000.0	5232900.0	50.00	980451.86	980454.07	1.10	8.72

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0499	480600.0	5234000.0	81.00	980444.18	980453.18	1.20	8.13
8700.0500	496000.0	5235650.0	64.00	980446.59	980451.87	1.65	8.96
8700.0501	495400.0	5235100.0	128.00	980434.58	980452.31	1.26	8.71
8700.0502	494550.0	5234350.0	297.00	980399.93	980452.92	2.03	7.46
8700.0503	494550.0	5233900.0	365.00	980386.96	980453.28	1.85	7.32
8700.0504	496600.0	5234000.0	281.00	980404.45	980453.20	1.76	8.28
8700.0505	496300.0	5233150.0	365.00	980390.34	980453.89	1.27	9.51
8700.0506	496700.0	5232250.0	422.00	980380.92	980454.62	1.44	10.74
8700.0507	497200.0	5224500.0	28.00	980467.83	980460.91	1.48	13.91
8700.0508	496450.0	5225000.0	64.00	980460.27	980460.50	1.90	14.25
8700.0509	495550.0	5225750.0	197.00	980434.65	980459.89	0.72	14.23
8700.0510	494700.0	5224850.0	266.00	980418.24	980460.62	1.33	11.27
8700.0511	494800.0	5224200.0	207.00	980430.64	980461.15	1.55	11.76
8700.0512	493550.0	5223200.0	99.00	980449.81	980461.96	1.30	8.62
8700.0513	501250.0	5230800.0	11.00	980467.59	980455.80	1.86	15.81
8700.0514	499400.0	5231650.0	137.00	980439.40	980455.11	1.57	12.81
8700.0515	498550.0	5232200.0	232.00	980418.83	980454.66	1.63	11.43
8700.0516	498500.0	5232600.0	246.00	980416.23	980454.34	1.80	12.08
8700.0517	499500.0	5229800.0	101.00	980448.69	980456.61	2.20	14.15
8700.0518	498700.0	5229850.0	201.00	980429.18	980456.57	2.60	14.75
8700.0519	497800.0	5229900.0	316.00	980404.85	980456.53	1.85	12.33
8700.0520	496800.0	5230000.0	434.00	980382.60	980456.45	0.93	12.45
8700.0521	496200.0	5229850.0	453.00	980379.33	980456.57	0.96	12.83
8700.0522	502750.0	5226900.0	43.00	980464.49	980458.96	0.64	14.62
8700.0523	501400.0	5227150.0	2.00	980472.34	980458.76	0.52	14.49
8700.0524	502000.0	5227050.0	10.00	980470.86	980458.84	0.56	14.54
8700.0525	501850.0	5226350.0	19.00	980470.14	980459.41	0.55	15.02
8700.0526	500800.0	5225550.0	2.00	980475.06	980460.06	0.51	15.90
8700.0527	500500.0	5224700.0	2.00	980476.10	980460.75	0.54	16.28
8700.0528	501400.0	5225400.0	58.00	980463.70	980460.18	0.67	15.60
8700.0529	514250.0	5235550.0	523.00	980355.25	980451.94	1.93	8.12
8700.0530	477000.0	5228050.0	38.00	980443.94	980458.00	1.15	-5.44
8700.0531	477350.0	5227350.0	64.00	980439.52	980458.57	1.56	-4.89
8700.0532	477500.0	5226500.0	71.00	980438.50	980459.26	1.85	-4.94
8700.0533	477650.0	5225450.0	98.00	980433.50	980460.11	2.95	-4.38
8700.0534	477200.0	5224550.0	141.00	980424.38	980460.84	2.47	-6.25
8700.0535	476600.0	5223600.0	74.00	980439.07	980461.60	4.66	-3.32
8700.0536	476100.0	5222000.0	71.00	980439.04	980462.90	4.28	-5.62
8700.0537	475550.0	5221000.0	83.00	980437.23	980463.71	3.91	-6.24
8700.0538	474650.0	5220500.0	160.00	980423.55	980464.11	2.95	-6.14
8700.0539	473750.0	5220050.0	177.00	980416.32	980464.48	3.00	-10.34
8700.0540	473300.0	5219000.0	167.00	980418.87	980465.33	3.67	-9.93
8700.0541	472600.0	5218250.0	173.00	980416.87	980465.93	2.80	-12.23
8700.0542	471700.0	5218200.0	222.00	980407.19	980465.97	3.25	-11.86
8700.0543	470900.0	5218000.0	226.00	980405.04	980466.13	4.28	-12.35
8700.0544	470000.0	5217800.0	301.00	980390.92	980466.29	3.90	-12.26
8700.0545	472450.0	5217550.0	133.00	980424.83	980466.50	2.80	-12.71
8700.0546	473250.0	5216600.0	144.00	980423.33	980467.27	2.81	-12.80
8700.0547	473350.0	5215800.0	177.00	980416.61	980467.92	3.27	-13.22
8700.0548	473100.0	5214700.0	176.00	980417.98	980468.81	2.60	-13.61
8700.0549	472650.0	5214000.0	155.00	980422.62	980469.38	2.50	-13.77
8700.0550	472250.0	5213000.0	139.00	980424.53	980470.19	2.53	-15.79
8700.0551	504200.0	5225700.0	215.00	980431.99	980459.93	0.96	15.31
8700.0552	504600.0	5226100.0	267.00	980421.52	980459.61	1.20	15.63

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0553	505250.0	5221800.0	48.00	980468.96	980463.10	0.64	15.94
8700.0554	504250.0	5221350.0	113.00	980456.64	980463.46	0.82	16.23
8700.0555	503750.0	5221500.0	152.00	980449.29	980463.34	0.78	16.62
8700.0556	503700.0	5222200.0	202.00	980439.10	980462.77	1.20	17.26
8700.0557	503850.0	5222500.0	226.00	980433.06	980462.53	1.15	16.14
8700.0558	502900.0	5222400.0	256.00	980426.56	980462.61	0.92	15.23
8700.0559	501650.0	5221600.0	197.00	980438.83	980463.26	0.94	15.26
8700.0560	500650.0	5222000.0	81.00	980462.36	980462.93	0.65	16.01
8700.0561	505400.0	5220900.0	54.00	980467.41	980463.83	0.75	14.96
8700.0562	504500.0	5220300.0	112.00	980456.26	980464.31	0.95	14.93
8700.0563	503550.0	5220350.0	192.00	980441.27	980464.27	0.70	15.47
8700.0564	502750.0	5220250.0	237.00	980431.79	980464.35	0.85	14.91
8700.0565	504550.0	5219650.0	196.00	980436.90	980464.84	0.70	11.31
8700.0566	503950.0	5219450.0	128.00	980450.28	980465.00	0.93	11.39
8700.0567	503900.0	5217450.0	84.00	980462.94	980466.62	1.00	13.84
8700.0568	503600.0	5217400.0	105.00	980459.67	980466.66	1.15	14.81
8700.0569	503500.0	5216750.0	238.00	980431.82	980467.19	1.80	13.25
8700.0570	505000.0	5219600.0	141.00	980448.82	980464.88	0.80	12.48
8700.0571	505400.0	5219550.0	110.00	980455.55	980464.92	0.75	13.02
8700.0572	506150.0	5219600.0	27.00	980471.83	980464.88	0.58	12.84
8700.0573	506500.0	5219800.0	1.00	980478.05	980464.72	0.52	14.05
8700.0574	506750.0	5220650.0	3.00	980478.34	980464.03	0.69	15.59
8700.0575	508150.0	5221950.0	168.00	980446.86	980462.97	1.35	18.29
8700.0576	509350.0	5222250.0	303.00	980419.66	980462.73	2.20	18.73
8700.0577	510400.0	5222800.0	415.00	980399.43	980462.28	2.25	21.03
8700.0578	509900.0	5223700.0	410.00	980401.04	980461.55	1.86	21.99
8700.0579	510050.0	5224400.0	442.00	980390.52	980460.98	1.65	18.13
8700.0580	510400.0	5225100.0	451.00	980387.18	980460.41	1.45	16.92
8700.0581	510400.0	5225900.0	430.00	980392.09	980459.77	1.26	18.17
8700.0582	509150.0	5224700.0	335.00	980412.41	980460.74	1.35	18.92
8700.0583	508150.0	5224500.0	240.00	980428.14	980460.90	2.40	16.84
8700.0584	507150.0	5224200.0	106.00	980457.78	980461.15	1.80	19.29
8700.0585	507400.0	5225250.0	92.00	980456.86	980460.30	2.12	16.78
8700.0586	507600.0	5226000.0	135.00	980448.19	980459.69	2.67	17.72
8700.0587	508700.0	5219900.0	20.00	980477.90	980464.63	0.65	17.85
8700.0588	509500.0	5220200.0	24.00	980477.59	980464.39	0.80	18.72
8700.0589	510400.0	5220650.0	39.00	980474.33	980464.02	1.10	19.08
8700.0590	511350.0	5220950.0	63.00	980470.33	980463.78	1.45	20.39
8700.0591	511850.0	5221600.0	56.00	980470.23	980463.25	1.25	19.24
8700.0592	513900.0	5220100.0	252.00	980432.10	980464.46	1.15	18.35
8700.0593	514800.0	5220250.0	367.00	980407.79	980464.34	2.20	17.84
8700.0594	515700.0	5220100.0	337.00	980417.18	980464.46	1.60	20.60
8700.0595	516550.0	5220150.0	280.00	980426.97	980464.42	1.62	19.24
8700.0596	517250.0	5220500.0	205.00	980444.35	980464.13	1.12	21.66
8700.0597	518150.0	5220900.0	93.00	980464.26	980463.81	0.85	19.60
8700.0598	519050.0	5221200.0	22.00	980476.87	980463.56	0.67	18.31
8700.0599	519500.0	5221250.0	1.50	980479.99	980463.52	0.60	17.37
8700.0600	494100.0	5239600.0	41.00	980447.74	980448.66	2.27	9.41
8700.0601	494650.0	5240500.0	69.00	980441.56	980447.93	2.20	9.40
8700.0602	495750.0	5241450.0	108.00	980432.70	980447.16	2.73	9.51
8700.0603	495950.0	5241900.0	109.00	980430.68	980446.80	2.82	8.14
8700.0604	496450.0	5242150.0	124.00	980427.42	980446.60	2.98	8.20
8700.0605	497050.0	5241900.0	196.00	980414.01	980446.80	3.86	9.62
8700.0606	496750.0	5242450.0	139.00	980425.35	980446.35	3.60	9.94

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0607	496200.0	5242800.0	118.00	980426.09	980446.07	4.30	7.53
8700.0608	496200.0	5243800.0	192.00	980408.46	980445.26	6.80	7.76
8700.0609	496600.0	5244650.0	183.00	980406.13	980444.57	7.20	4.76
8700.0610	496850.0	5245800.0	235.00	980395.43	980443.64	6.53	4.55
8700.0611	497500.0	5247700.0	400.00	980358.17	980442.10	3.05	-2.20
8700.0612	497900.0	5248800.0	530.00	980333.26	980441.21	2.80	-0.90
8700.0613	498000.0	5249400.0	590.00	980321.11	980440.72	2.60	-0.95
8700.0614	493400.0	5239900.0	40.00	980445.24	980448.42	2.47	7.16
8700.0615	493300.0	5240850.0	90.00	980434.86	980447.65	2.80	7.72
8700.0616	493150.0	5241850.0	232.00	980408.46	980446.84	3.50	10.75
8700.0617	493150.0	5242850.0	395.00	980373.03	980446.03	3.70	8.40
8700.0618	493300.0	5243600.0	420.00	980368.70	980445.42	3.33	9.22
8700.0619	493350.0	5244500.0	587.00	980330.84	980444.69	3.67	5.29
8700.0620	493500.0	5245550.0	715.00	980305.24	980443.84	2.87	4.91
8700.0621	511250.0	5217900.0	132.00	980458.82	980466.25	1.13	19.67
8700.0622	512400.0	5218000.0	302.00	980421.09	980466.17	1.60	15.93
8700.0623	513100.0	5218850.0	170.00	980449.11	980465.48	1.18	18.25
8700.0624	512650.0	5219600.0	110.00	980462.60	980464.87	1.27	20.63
8700.0625	513200.0	5219450.0	152.00	980452.30	980464.99	1.15	18.36
8700.0626	513800.0	5218800.0	263.00	980430.05	980465.52	2.13	18.39
8700.0627	514450.0	5218600.0	362.00	980409.88	980465.68	2.44	17.84
8700.0628	514300.0	5217750.0	368.00	980409.93	980466.37	2.28	18.23
8700.0629	508550.0	5218350.0	2.50	980481.61	980465.89	0.53	16.74
8700.0630	509950.0	5217200.0	84.00	980468.77	980466.82	0.80	19.27
8700.0631	510350.0	5217000.0	109.00	980463.61	980466.98	1.00	19.07
8700.0632	510050.0	5215900.0	32.00	980479.10	980467.88	0.84	18.36
8700.0633	510950.0	5215800.0	143.00	980455.71	980467.96	0.85	16.73
8700.0634	512000.0	5216550.0	304.00	980421.69	980467.35	1.16	15.30
8700.0635	512250.0	5217000.0	352.00	980411.21	980466.98	1.22	14.69
8700.0636	509300.0	5215650.0	1.00	980483.16	980468.08	0.43	15.71
8700.0637	510325.0	5215200.0	36.00	980477.12	980468.44	0.69	16.45
8700.0638	511700.0	5208900.0	2.50	980490.39	980473.55	0.55	17.88
8700.0639	512700.0	5209500.0	117.00	980469.04	980473.06	0.88	19.87
8700.0640	513050.0	5210100.0	133.00	980464.19	980472.58	0.96	18.74
8700.0641	518150.0	5209550.0	222.00	980444.94	980473.01	2.45	18.04
8700.0642	518750.0	5210050.0	122.00	980464.30	980472.61	1.00	16.69
8700.0643	519650.0	5210900.0	107.00	980467.00	980471.92	0.75	16.88
8700.0644	517425.0	5211150.0	204.00	980446.77	980471.72	1.15	16.33
8700.0645	516650.0	5211550.0	318.00	980423.93	980471.39	2.30	17.39
8700.0646	519100.0	5211850.0	45.00	980478.51	980471.15	0.80	17.01
8700.0647	518050.0	5212050.0	112.00	980463.73	980470.99	1.48	16.25
8700.0648	520500.0	5212400.0	1.50	980487.15	980470.70	0.60	17.35
8700.0649	520750.0	5213150.0	1.50	980487.38	980470.09	0.73	18.32
8700.0650	520900.0	5213650.0	13.00	980483.44	980469.68	0.80	17.12
8700.0651	519200.0	5212650.0	58.00	980475.18	980470.50	1.43	17.52
8700.0652	518000.0	5212700.0	194.00	980447.28	980470.46	1.20	16.18
8700.0653	518400.0	5216200.0	275.00	980429.89	980467.62	2.50	18.86
8700.0654	518100.0	5218550.0	117.00	980461.02	980465.71	2.00	20.33
8700.0655	517550.0	5218350.0	204.00	980443.36	980465.88	3.15	20.76
8700.0656	511550.0	5211150.0	2.00	980484.88	980471.73	0.77	14.31
8700.0657	514200.0	5214450.0	42.00	980475.21	980469.05	1.08	15.50
8700.0658	515150.0	5216075.0	95.00	980465.01	980467.73	1.80	17.77
8700.0659	515350.0	5214150.0	140.00	980456.31	980469.29	1.08	15.64
8700.0660	512950.0	5222600.0	101.00	980461.47	980462.44	1.45	20.35

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8700.0661	512600.0	5225200.0	125.00	980450.59	980460.33	1.95	16.79
8700.0662	503500.0	5227000.0	81.00	980456.18	980458.88	1.08	14.31
8700.0663	506550.0	5227500.0	345.00	980403.54	980458.47	3.00	15.93
8700.0664	507450.0	5227900.0	420.00	980387.69	980458.15	3.65	15.81
8700.0665	508450.0	5228000.0	575.00	980356.40	980458.07	3.70	15.14
8700.0666	509500.0	5228150.0	673.00	980339.77	980457.94	2.40	16.60
8700.0667	510350.0	5228450.0	621.00	980350.93	980457.70	2.00	17.38
8700.0668	510750.0	5228800.0	600.00	980355.39	980457.41	2.21	18.21
8700.0669	511600.0	5229100.0	576.00	980358.82	980457.17	1.30	16.25
8700.0670	512100.0	5229450.0	563.00	980360.54	980456.89	1.40	15.80
8700.0671	512750.0	5230100.0	607.00	980350.57	980456.36	0.73	14.34
8700.0672	513150.0	5230750.0	606.00	980349.90	980455.83	0.81	14.08
8700.0673	512250.0	5230800.0	560.00	980358.55	980455.79	0.84	13.75
8700.0674	514150.0	5231350.0	663.00	980337.04	980455.34	1.80	13.91
8700.0675	514250.0	5232300.0	626.00	980343.04	980454.57	2.54	14.14
8700.0676	513650.0	5233250.0	432.00	980376.10	980453.80	3.39	10.67
8700.0677	513300.0	5234200.0	396.00	980382.66	980453.03	2.13	9.65
8700.0678	513900.0	5236300.0	498.00	980359.82	980451.33	2.43	8.88
8700.0679	513300.0	5223850.0	147.00	980451.28	980461.42	1.35	20.13
8700.0680	513900.0	5223650.0	259.00	980428.62	980461.59	1.10	19.08
8700.0681	519800.0	5227150.0	34.00	980468.97	980458.73	0.85	17.77
8700.0682	518000.0	5227950.0	89.00	980458.23	980458.09	2.13	19.78
8700.0683	518350.0	5228250.0	163.00	980444.50	980457.85	2.41	21.13
8700.0684	520200.0	5224750.0	2.00	980477.96	980460.68	0.60	18.28
8700.0685	519100.0	5225450.0	41.00	980471.76	980460.12	0.97	20.68
8700.0686	518200.0	5225350.0	102.00	980460.75	980460.20	1.25	21.87
8700.0687	517600.0	5225200.0	107.00	980460.01	980460.32	1.86	22.59
8700.0688	516700.0	5224900.0	224.00	980437.32	980460.57	1.80	22.62
8700.0689	518700.0	5223400.0	92.00	980463.13	980461.78	1.18	20.63
8700.0690	517650.0	5223500.0	188.00	980447.29	980461.70	1.86	24.43
8700.0691	516250.0	5223800.0	346.00	980414.84	980461.46	3.73	25.16
8700.0692	515600.0	5224100.0	491.00	980380.84	980461.22	5.47	21.67
8700.0693	515250.0	5223650.0	452.00	980392.52	980461.58	3.27	23.11
8700.0694	518200.0	5222000.0	72.00	980467.99	980462.92	1.33	20.57
8700.0695	517700.0	5221800.0	100.00	980463.89	980463.08	1.65	22.13
8700.0696	518750.0	5222550.0	67.00	980468.41	980462.47	1.22	20.34
8700.0697	523200.0	5223050.0	1.50	980482.63	980462.05	0.33	21.20
8700.0698	523950.0	5223200.0	49.00	980473.69	980461.93	0.65	22.05
8700.0699	524450.0	5223050.0	87.00	980467.25	980462.05	0.71	23.03
8700.0700	525000.0	5222600.0	87.00	980467.81	980462.41	0.55	23.06
8700.0701	524650.0	5222000.0	93.00	980466.70	980462.90	0.68	22.77
8700.0702	524250.0	5221400.0	28.00	980478.94	980463.39	0.62	21.68
8700.0703	523900.0	5221400.0	1.50	980484.33	980463.39	0.56	21.80
8700.0704	522950.0	5221250.0	20.00	980479.83	980463.51	0.35	20.60
8700.0705	522900.0	5220350.0	1.00	980484.95	980464.24	0.24	21.14
8700.0706	523550.0	5220350.0	23.00	980481.65	980464.24	0.35	22.28
8700.0707	524250.0	5220300.0	2.50	980485.61	980464.28	0.73	22.56
8700.0708	524750.0	5220850.0	50.00	980476.65	980463.83	0.68	23.33
8700.0709	524700.0	5220250.0	37.00	980480.38	980464.32	0.85	24.20
8700.0710	525400.0	5222550.0	62.00	980472.51	980462.45	0.45	22.71
8700.0711	524200.0	5223450.0	23.00	980479.56	980461.72	0.30	22.66
8700.0712	525900.0	5223950.0	0.50	980482.87	980461.31	0.17	21.82
8700.0713	526150.0	5222350.0	31.00	980477.74	980462.61	0.55	21.78
8700.0714	525950.0	5222000.0	98.00	980464.32	980462.89	0.95	21.65

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8700.0715	525800.0	5221500.0	171.00	980449.85	980463.30	1.80	21.99
8700.0716	525900.0	5221150.0	206.00	980442.32	980463.58	2.05	21.31
8700.0717	525950.0	5220700.0	176.00	980449.13	980463.95	2.33	22.13
8700.0718	531500.0	5220800.0	19.00	980484.29	980463.85	0.16	24.34
8700.0719	532850.0	5219800.0	114.00	980467.05	980464.65	1.00	25.82
8700.0720	532900.0	5218850.0	119.00	980468.80	980465.43	1.10	27.88
8700.0721	533150.0	5218600.0	130.00	980466.69	980465.63	1.72	28.35
8700.0722	527700.0	5220100.0	3.00	980486.62	980464.43	0.22	23.00
8700.0723	527350.0	5219350.0	1.00	980487.77	980465.04	0.18	23.11
8700.0724	526900.0	5220100.0	1.00	980486.21	980464.43	0.32	22.29
8700.0725	526100.0	5219600.0	1.00	980485.35	980464.84	0.84	21.55
8700.0726	525350.0	5219200.0	1.00	980486.73	980465.17	0.76	22.52
8700.0727	524200.0	5219200.0	1.00	980488.38	980465.17	0.37	23.78
8700.0728	524300.0	5219900.0	1.00	980487.27	980464.60	0.45	23.31
8700.0729	523700.0	5219550.0	1.00	980487.91	980464.89	0.20	23.42
8700.0730	526800.0	5218700.0	1.00	980489.59	980465.57	0.10	24.32
8700.0731	528000.0	5218350.0	1.00	980490.57	980465.85	0.35	25.27
8700.0732	528900.0	5218400.0	1.00	980490.50	980465.81	0.24	25.13
8700.0733	529250.0	5219000.0	1.00	980489.74	980465.32	0.21	24.83
8700.0734	519450.0	5190100.0	1.00	980514.89	980488.79	0.21	26.50
8700.0735	518600.0	5191000.0	0.50	980511.58	980488.06	0.17	23.78
8700.0736	517750.0	5190750.0	0.50	980510.24	980488.27	0.15	22.22
8700.0737	517100.0	5190750.0	0.50	980508.48	980488.27	0.12	20.43
8700.0738	516750.0	5190900.0	0.50	980507.82	980488.15	0.13	19.90
8700.0739	532100.0	5220600.0	1.00	980489.47	980464.01	0.14	25.80
8700.0740	532250.0	5219250.0	33.00	980486.81	980465.10	0.20	28.40
8700.0741	532200.0	5218900.0	73.00	980477.42	980465.39	0.37	26.76
8700.0742	531800.0	5218700.0	30.00	980486.13	980465.55	0.19	26.67
8700.0743	531550.0	5219150.0	12.00	980487.89	980465.19	0.20	25.27
8700.0744	532900.0	5217950.0	132.00	980466.37	980466.15	1.30	27.48
8700.0745	532250.0	5217900.0	40.00	980486.27	980466.20	0.25	28.19
8700.0746	531900.0	5218250.0	20.00	980489.29	980465.92	0.15	27.46
8700.0747	532850.0	5217600.0	111.00	980472.05	980466.44	1.08	28.52
8700.0748	533050.0	5214750.0	160.00	980464.37	980468.75	1.10	28.19
8700.0749	533000.0	5214150.0	178.00	980462.63	980469.24	1.70	30.11
8700.0750	532950.0	5213150.0	177.00	980464.24	980470.05	1.60	30.61
8700.0751	532750.0	5212350.0	96.00	980481.59	980470.70	1.00	30.77
8700.0752	532450.0	5211950.0	1.50	980501.51	980471.02	0.44	31.22
8700.0753	531200.0	5211450.0	10.00	980498.16	980471.43	0.15	28.84
8700.0754	531800.0	5212200.0	2.00	980500.36	980470.82	0.25	30.18
8700.0755	531025.0	5212600.0	3.00	980498.50	980470.50	0.16	28.75
8700.0756	530700.0	5213400.0	8.00	980497.13	980469.85	0.16	29.01
8700.0757	530125.0	5213900.0	15.00	980494.03	980469.45	0.23	27.76
8700.0758	530150.0	5214600.0	5.00	980495.76	980468.88	0.20	28.06
8700.0759	531400.0	5214350.0	121.00	980475.78	980469.08	2.00	32.50
8700.0760	531100.0	5214850.0	85.00	980482.47	980468.68	0.69	31.21
8700.0761	531450.0	5215050.0	61.00	980486.44	980468.51	0.32	30.25
8700.0762	496700.0	5238100.0	42.00	980450.56	980449.88	2.23	11.17
8700.0763	497350.0	5237000.0	53.00	980448.40	980450.77	2.13	10.18
8700.0764	498600.0	5237250.0	68.00	980445.73	980450.57	1.92	10.46
8700.0765	499850.0	5238150.0	184.00	980422.30	980449.84	2.43	11.09
8700.0766	498100.0	5238800.0	407.00	980375.96	980449.31	4.20	10.91
8700.0767	491550.0	5240150.0	32.00	980445.50	980448.21	3.00	6.58
8700.0768	490250.0	5240500.0	44.00	980444.29	980447.93	2.11	7.13

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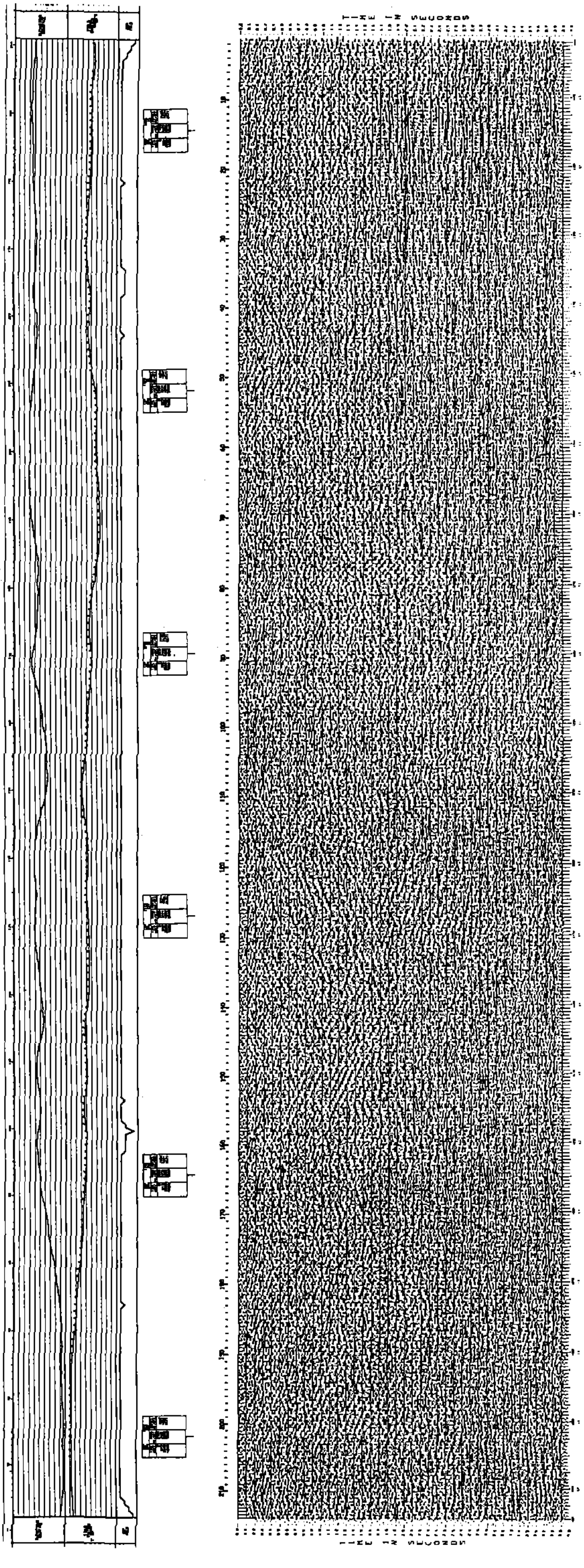
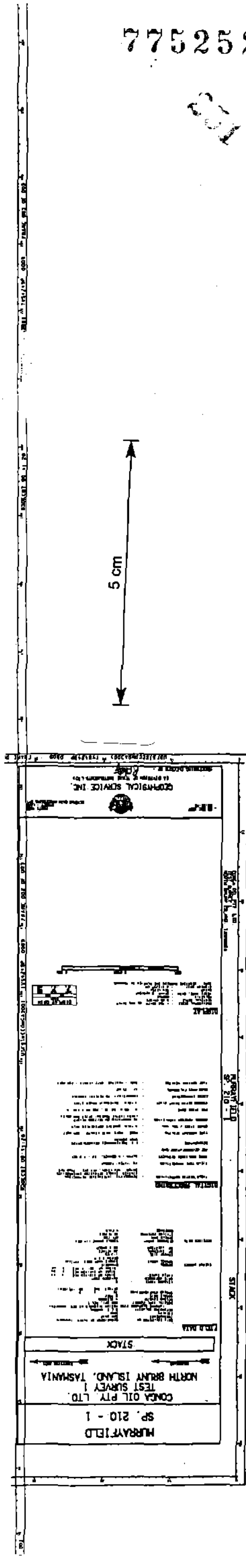
NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0769	488250.0	5241400.0	51.00	980446.37	980447.20	2.07	11.27
8700.0770	487600.0	5242350.0	86.00	980442.62	980446.43	2.73	15.84
8700.0771	488250.0	5240750.0	42.00	980446.87	980447.72	2.15	9.56
8700.0772	487025.0	5241500.0	58.00	980444.56	980447.11	2.45	11.31
8700.0773	486450.0	5242400.0	71.00	980444.28	980446.38	2.60	14.46
8700.0774	485500.0	5243250.0	83.00	980438.49	980445.69	2.55	11.67
8700.0775	485300.0	5244250.0	107.00	980431.69	980444.88	3.06	10.92
8700.0776	485450.0	5245050.0	142.00	980420.24	980444.23	3.88	7.81
8700.0777	485950.0	5245900.0	199.00	980405.56	980443.55	5.36	6.52
8700.0778	484000.0	5244200.0	103.00	980431.71	980444.92	2.90	9.95
8700.0779	483200.0	5244900.0	113.00	980428.16	980444.35	3.05	9.09
8700.0780	482100.0	5245300.0	152.00	980418.86	980444.02	2.90	7.64
8700.0781	482250.0	5244050.0	333.00	980386.10	980445.04	3.21	9.77
8700.0782	482850.0	5243850.0	389.00	980373.10	980445.20	2.90	7.31
8700.0783	483050.0	5245950.0	214.00	980405.36	980443.50	2.51	6.46
8700.0784	482800.0	5246500.0	260.00	980392.95	980443.05	4.13	5.17
8700.0785	482700.0	5247950.0	407.00	980361.00	980441.88	3.33	2.51
8700.0786	481500.0	5248350.0	415.00	980354.60	980441.55	3.73	-1.59
8700.0787	480700.0	5250000.0	534.00	980328.29	980440.21	3.70	-3.18
8700.0788	480150.0	5248950.0	421.00	980352.17	980441.06	4.00	-2.09
8700.0789	478900.0	5250100.0	373.00	980358.66	980440.13	2.93	-5.16
8700.0790	478200.0	5250100.0	381.00	980356.94	980440.12	3.33	-4.92
8700.0791	477750.0	5251400.0	458.00	980339.67	980439.07	3.50	-5.82
8700.0792	476800.0	5250500.0	506.00	980331.16	980439.80	2.80	-6.31
8700.0793	478100.0	5249500.0	432.00	980348.12	980440.61	2.08	-5.43
8700.0794	479100.0	5248100.0	518.00	980334.70	980441.75	2.63	-2.53
8700.0795	476500.0	5249500.0	494.00	980336.21	980440.61	1.93	-5.29
8700.0796	487050.0	5240300.0	185.00	980419.98	980448.09	2.27	10.56
8700.0797	484550.0	5239450.0	87.00	980442.96	980448.77	1.18	12.48
8700.0798	483400.0	5240700.0	93.00	980437.74	980447.76	2.46	10.74
8700.0799	482650.0	5241650.0	108.00	980432.59	980446.98	2.16	9.01
8700.0800	481800.0	5242550.0	120.00	980427.74	980446.25	2.41	7.50
8700.0801	480700.0	5241900.0	150.00	980421.08	980446.78	2.44	6.25
8700.0802	479950.0	5240450.0	277.00	980397.77	980447.95	2.72	7.02
8700.0803	480800.0	5243200.0	200.00	980408.99	980445.72	1.80	4.41
8700.0804	480150.0	5243750.0	252.00	980398.03	980445.28	1.73	4.05
8700.0805	478900.0	5245650.0	383.00	980368.58	980443.73	2.36	2.55
8700.0806	502700.0	5234100.0	106.00	980442.27	980453.12	2.53	12.53
8700.0807	501900.0	5234050.0	253.00	980414.71	980453.16	2.66	13.98
8700.0808	500500.0	5234300.0	405.00	980380.76	980452.96	4.09	11.55
8700.0809	501400.0	5233150.0	136.00	980438.38	980453.89	2.47	13.71
8700.0810	500800.0	5232600.0	252.00	980417.13	980454.34	2.41	14.77
8700.0811	500450.0	5233300.0	350.00	980396.74	980453.77	2.80	14.61
8700.0812	496350.0	5218300.0	58.00	980461.18	980465.93	0.60	7.25
8700.0813	497200.0	5219100.0	21.00	980469.43	980465.29	0.81	9.09
8700.0814	495950.0	5219000.0	89.00	980456.47	980465.37	0.84	9.45
8700.0815	495425.0	5219750.0	30.00	980466.84	980464.76	0.90	8.88
8700.0816	504725.0	5233350.0	193.00	980428.42	980453.73	3.70	16.35
8700.0817	505300.0	5233250.0	329.00	980400.14	980453.81	2.53	13.57
8700.0818	506150.0	5233950.0	475.00	980368.70	980453.24	3.67	12.56
8700.0819	505900.0	5233550.0	374.00	980388.10	980453.57	4.00	12.10
8700.0820	518200.0	5229900.0	258.00	980422.88	980456.51	1.56	18.68
8700.0821	517550.0	5229150.0	297.00	980414.93	980457.12	1.70	17.93
8700.0822	516700.0	5228650.0	370.00	980399.76	980457.53	1.81	16.83

NUMBER	EASTING	NORTHING	HEIGHT	OBS GRAV	THEO GRAV	CORR	BOUG ANOM
8700.0823	515500.0	5228650.0	530.00	980366.05	980457.53	2.44	15.21
8700.0824	521100.0	5225550.0	75.00	980464.96	980460.03	0.68	20.36
8700.0825	519700.0	5228400.0	98.00	980454.97	980457.72	0.82	17.34
8700.0826	520300.0	5229200.0	62.00	980462.54	980457.07	0.70	18.36
8700.0827	520450.0	5229600.0	42.00	980465.10	980456.75	0.65	17.27
8700.0828	521400.0	5229550.0	108.00	980451.58	980456.79	0.60	16.64
8700.0829	521500.0	5228850.0	160.00	980441.67	980457.35	0.95	16.74
8700.0830	521200.0	5228400.0	120.00	980450.84	980457.72	0.63	17.36
8700.0831	521400.0	5227800.0	81.00	980459.42	980458.20	0.58	17.73
8700.0832	521900.0	5227400.0	21.00	980473.11	980458.53	0.75	19.46
8700.0833	520000.0	5214500.0	56.00	980475.63	980468.99	1.08	18.73
8700.0834	519500.0	5214600.0	92.00	980467.37	980468.91	1.84	18.40
8700.0835	505900.0	5230150.0	75.00	980453.36	980456.32	1.24	13.03
8700.0836	506200.0	5229450.0	90.00	980450.59	980456.89	1.81	13.21
8700.0837	530500.0	5215350.0	1.00	980496.76	980468.27	0.38	29.06
8700.0838	529550.0	5215750.0	1.00	980494.91	980467.95	0.29	27.45
8700.0839	528300.0	5215350.0	1.00	980494.58	980468.28	0.10	26.59
8700.0840	527600.0	5214600.0	1.00	980494.86	980468.89	0.12	26.29
8700.0841	528250.0	5212050.0	1.00	980499.13	980470.96	0.15	28.52
8700.0842	528200.0	5212600.0	1.00	980498.33	980470.51	0.15	28.17
8700.0843	528800.0	5213000.0	1.00	980497.50	980470.18	0.10	27.62
8700.0844	528350.0	5213600.0	1.00	980497.57	980469.70	0.16	28.23
8700.0845	534100.0	5212550.0	33.00	980495.63	980470.53	0.38	31.97
8700.0846	533700.0	5213100.0	18.00	980497.44	980470.09	0.31	31.21
8700.0847	533850.0	5213650.0	25.00	980496.17	980469.64	0.27	31.72
8700.0848	533900.0	5214150.0	41.00	980492.43	980469.23	0.26	31.52
8700.0849	533750.0	5214700.0	49.00	980490.66	980468.79	0.30	31.81
8700.0850	523150.0	5230200.0	1.00	980471.54	980456.25	0.64	16.13

APPENDIX 8

775252




5 cm
MURRAYFIELD
SP. 210 - 1
CONGA OIL PTY. LTD.
TEST SURVEY 1
NORTH BRUNY ISLAND, TASMANIA
STACK
GEOPHYSICAL SERVICE INC.

775253

1987/53. An experimental seismic reflection survey on Bruny Island.

R. G. Richardson

Abstract

An experimental seismic reflection survey on North Bruny Island showed that the technique is applicable to the area studied. The recording parameters included 14 Hz geophones, 30 m group and shot interval, wideband reading, 1.0 to 1.5 kg charges, and 2.6 m deep shot holes. Despite the presence of a dolerite sill under much of the area, good quality reflections were obtained from below the dolerite.

INTRODUCTION

At the request of Conga Oil a test seismic reflection survey was undertaken on North Bruny Island (fig. 1). The Department has, for a number of years, been investigating the applicability of the reflection technique in a wide range of geological environments (Leaman, 1980) and the Bruny project represented an opportunity to integrate a number of previously developed techniques.

The near-surface geology included Permian sandstone, mudstone and limestone, and Jurassic dolerite. It was anticipated from other data that at least part of the area would be underlain by a dolerite sill. Shot holes were drilled to an average depth of 2.6 m using an airtrack, and most finished in slightly weathered or unweathered rock. Approximately 60 additional holes were drilled near the north and south ends of the traverse for testing different shot-receiver combinations. Shot holes were at a 30 m interval.

An Input-Output DHR 1632 eight-channel seismic system was used with a group interval of 30 m. This system offers 12 bit conversion, rudimentary signal processing on playback to the analogue plotter, and digital magnetic tape for data storage. The available geophones were 14 Hz, 28 Hz, and 40 Hz. A 500 Hz sample rate was used with no input filtering.

RESULTS

The test shots fired at the southern end of the traverse on the first two days of the project were, unfortunately, subject to very strong wind noise. Charges varying from 0.125 kg to 3 kg of gelignite were fired and recorded using all available geophone types. Although various replay filter bandwidths, automatic gain controls, and programmed gain controls were tried, the records were uniformly depressing (e.g. fig. 2). Perhaps the only consistent feature was the low amplitude zone between 750 and 1300 milliseconds.

At the northern end of the traverse the test shots were fired in quiet conditions and showed a number of coherent arrivals (fig. 3). Once again a low amplitude zone was present, but between 1900 and 2400 milliseconds. After testing with a range of shot sizes, geophones and playback parameters, the optimum conditions were found to be a shot size of between 1.0 and 1.5 kg of gelignite, 14 Hz geophones, a playback passband from 30 Hz to 120 Hz, and a programmed gain increase of 6 dB per second. Recording was wideband.

Recording of the traverse was from Shotpoint 210, at the northern end, to Shotpoint 1 at the southern end. With the 30 m shotpoint and trace interval a four-fold coverage was obtained. The topography varied from almost level to changes in elevation of up to eight metres between shotpoints. Figures 4 and 5 show typical field plots of data from channel 4 only. The low amplitude zones continue to be present, although they are not ubiquitous, and there are a number of coherent arrivals visible over groups of adjacent traces. Without processing, to correct at least for the topographic variation, little further information is expected.

Single fold expanded spreads were fired near both ends of the traverse (e.g. fig. 6) and showed a number of coherent arrivals. Once again there is a low amplitude zone.

CONCLUSIONS

The test survey showed that the seismic reflection technique can be used successfully in the area of North Bruny Island that was covered. The area consists of a number of fault blocks and it is inferred, from other geological and geophysical data, that energy is being transmitted through the dolerite, and the low amplitude zone corresponds to essentially homogenous Precambrian units.

Any production survey should use a wideband recording system with 14 Hz geophones and at least a 16 bit conversion. If a gelignite source is used shot holes should be drilled to a depth of six metres and cased with rigid PVC pipe.

REFERENCE

LEAMAN, D. E. 1978. Use of the reflection method in Tasmania. Part 1: Equipment, techniques and problems. *Geophys. spec. Rep. Dep. Mines Tasm.* 7.

[28 October 1987]

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775255

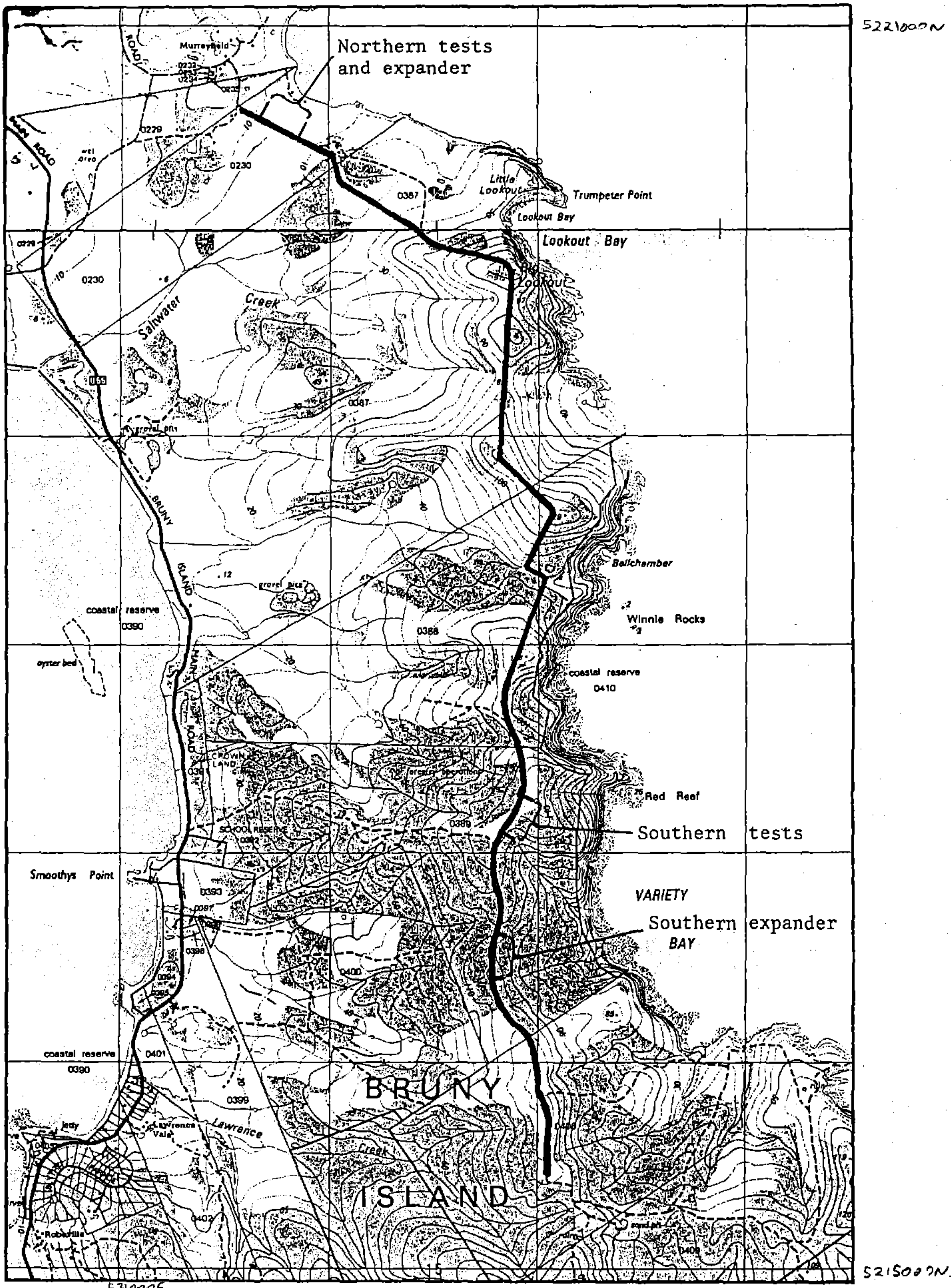


Figure 1. *Location of traverse.*

775256

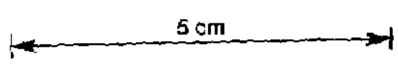
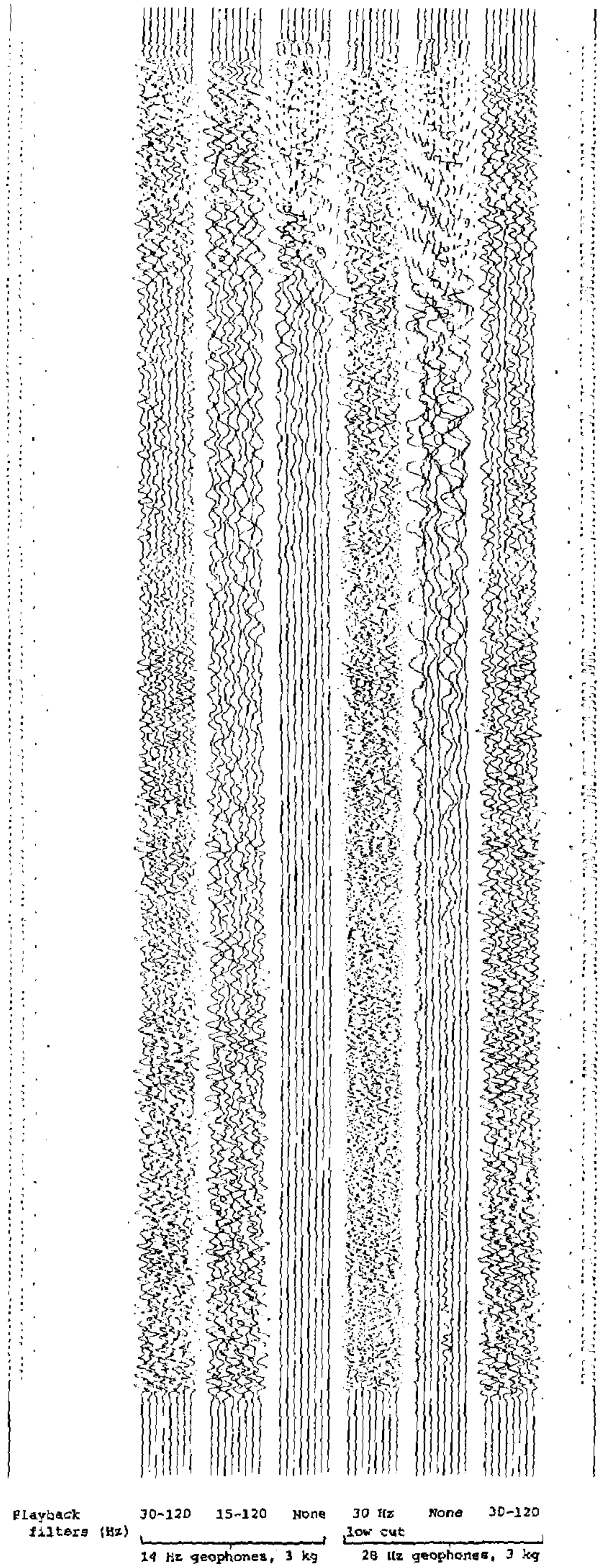


Figure 2. *Shotpoint 59*



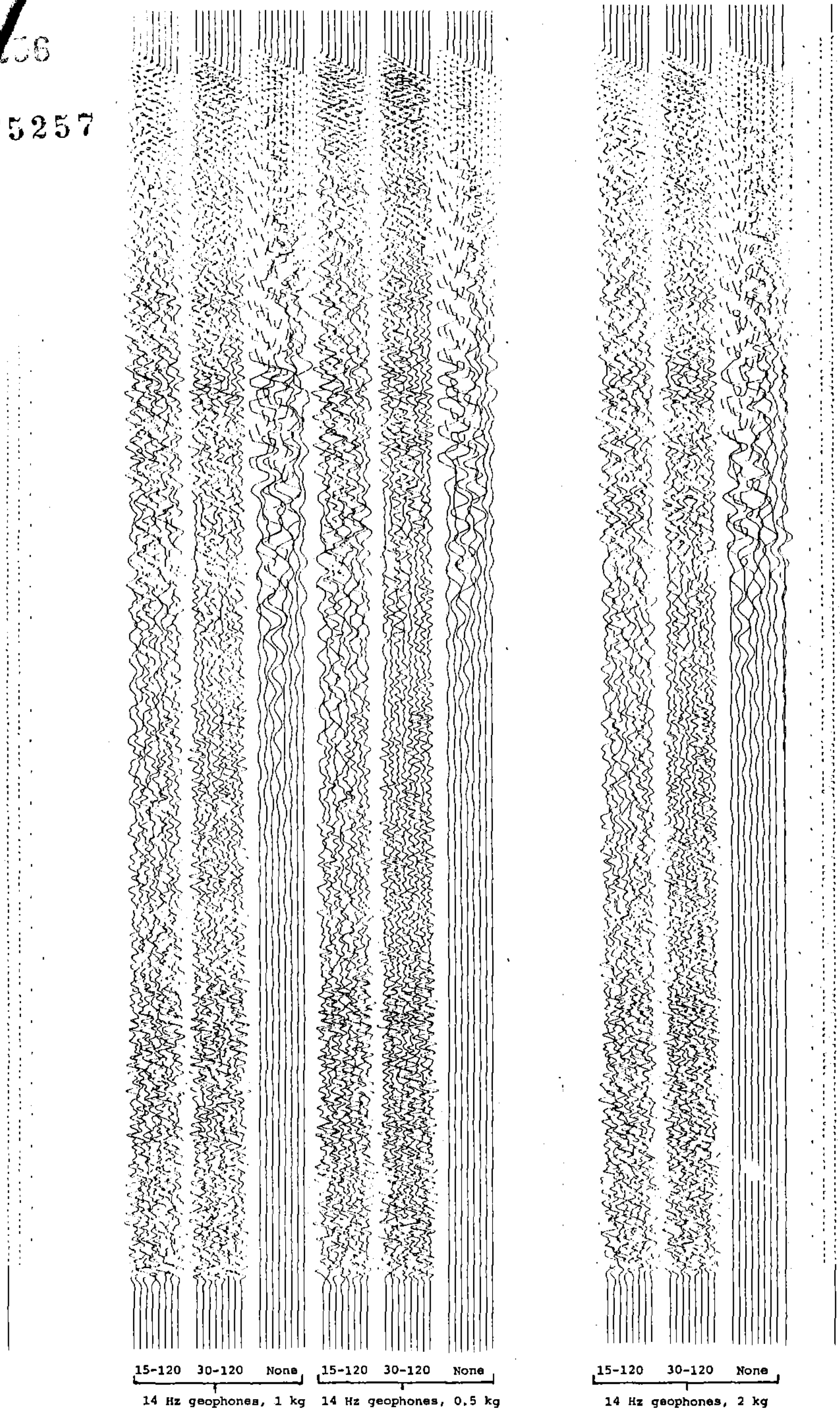


Figure 3. *Shotpoint 198 and 199.*

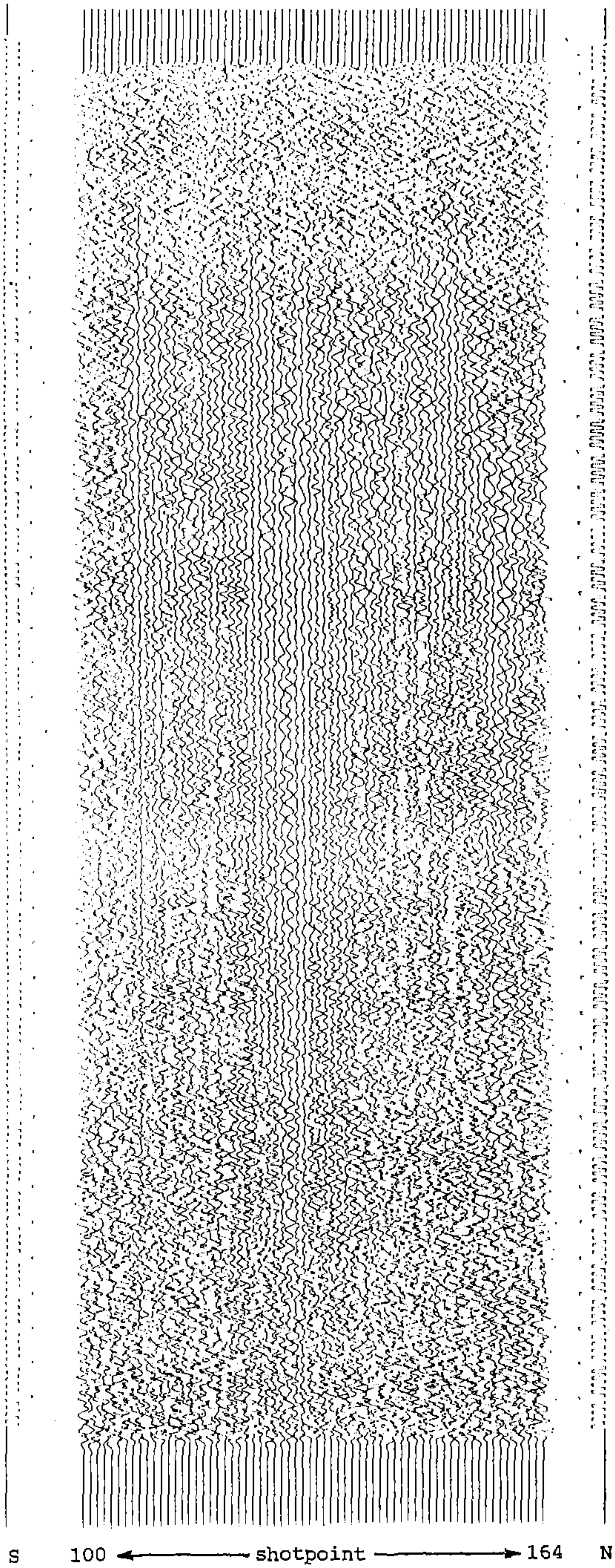


Figure 4. *Field plot - Channel 4*

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775259

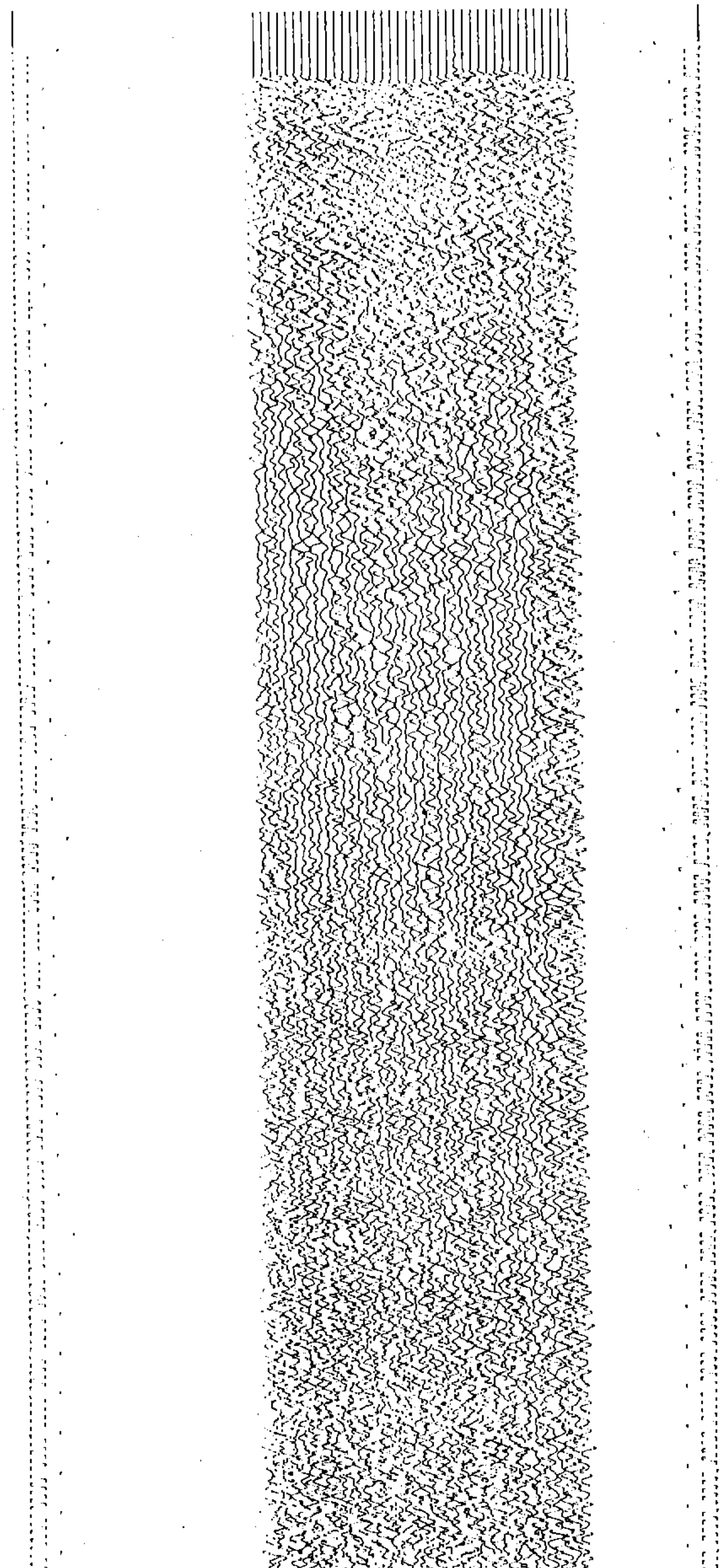

Figure 5. *Field plot - Channel 4*

209

775260

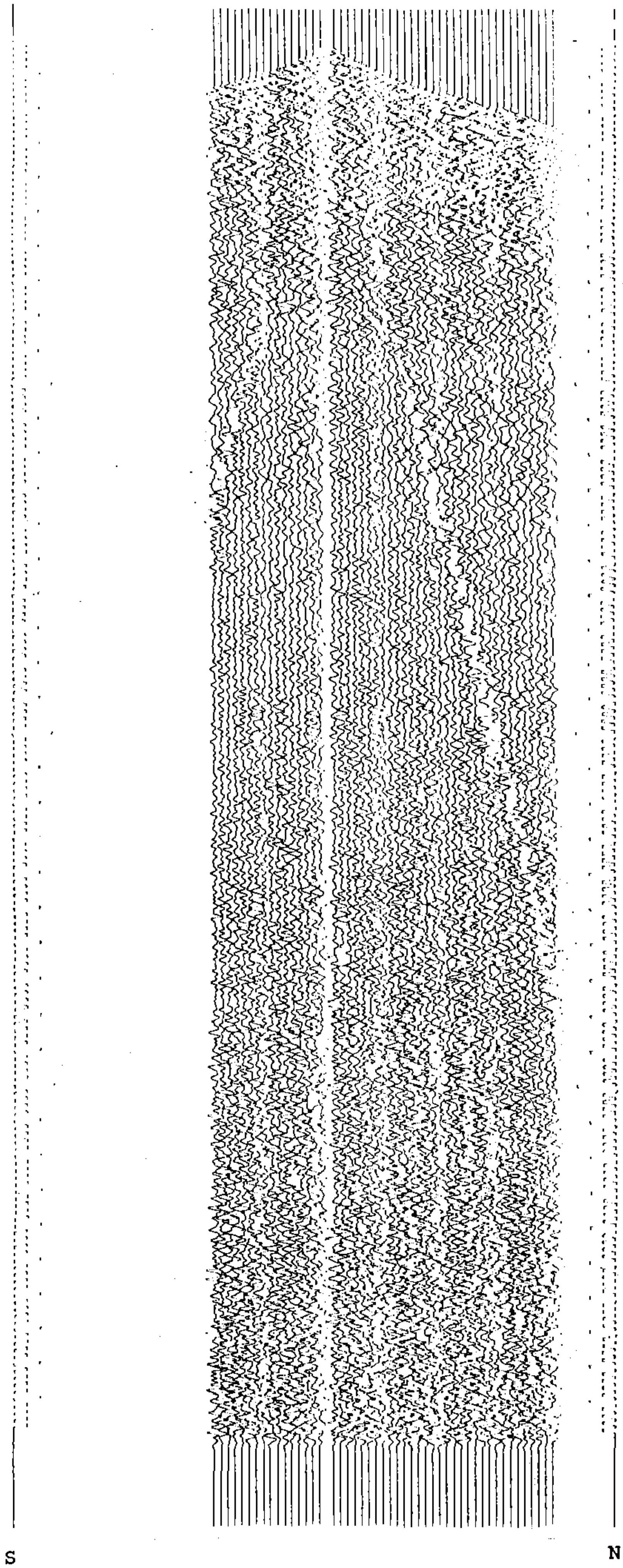

Figure 6. *Southern expanded spread*