

CONTENTS

INTRODUCTION	1
LICENCES (Ground held and applications)	1
EXPLORATION HISTORY, PHILOSOPHY AND PROPOSALS	
Outline	2
Progress to date	3
Programmes proposed	4
SUMMARY OF EXPLORATION OBJECTIVES	4
EXPENDITURE SUMMARY	5

APPENDICES:

1. Presentation to 1991 APEA Conference (M. Bendall, C. Burrett, D. Leaman, J. Volkman).
2. Presentation to 1991 Petroleum geochemistry conference (J. Volkman)
3. Diagrams and comments outlining current status of exploration and understanding.

INTRODUCTION

This is the sixth "annual" report submitted by Conga Oil Pty Ltd in respect of its petroleum exploration of onshore Tasmania. Information now available confirms that Tasmania must be treated seriously in terms of hydrocarbon, and in particular oil, exploration. Evaluation will be difficult and possibly extended initially due to lack of regional seismic coverage and previous deep drilling programmes, and the difficult alpine geological styles now established. The extent of seepage occurrences, however, suggests that it will ultimately prove very worthwhile.

It was noted in the last annual report that Conga's efforts to awaken interest in such exploration in Tasmania were proving successful. Recent presentations at the APEA conference in Melbourne (Appendices 1 and 2) have confirmed this and there are many expressions of interest. The lack of quality seismic data until very recently has dampened preparedness to farm-in given the classical difficulties of exploration in alpine or thrust terrains. There is, however, no doubt within the industry that Conga's efforts have been effective and demonstrate that Tasmania has been overlooked.

Conga Oil has been restricted during the year by cash flow problems in what are difficult times in Australia, both financially and politically - given environmental lobby groups actively campaigning against exploration or development.

As many projects as possible have been continued through this difficult period in order to avoid loss of momentum but mostly this has meant only steady and uneven progress. Key problems, such as how to give priority to target area selection for initial stratigraphic drilling, the specification and processing of seismic data, and identification of areas for possible relinquishment in 1992 have been reviewed and progress toward resolution achieved.

This report describes those activities undertaken since May 1990. Many projects are incomplete and this outline summarises current status.

LICENCES

Licence EL 1/88 is held in the name of Conga Oil Pty. Ltd., of Blackmans Bay, Tasmania. It is held for oil.

The licence is a consolidation of several pre-existing licences. The location of the licence area is shown in Figure 1. The consolidation has been deemed to date from June 10, 1989, although the actual granting was some five months later.

Following work undertaken during the past two years, as described in this report, and some consideration of the surprising implications of that work a further onshore application has been made (EL 17/90). This covers the bulk of Tasmania west of EL 1/88. Why an area composed largely of Precambrian rocks should be of interest is explained below. There are also, clearly, similar implications for adjacent offshore areas.

The new licence area may be advertised in the near future implying that administrative matters associated with its granting have been resolved.

EXPLORATION HISTORY AND OBJECTIVES

OUTLINE:

The exploration programme outlined in the 1989 and 1990 annual reports has been disrupted but is now being recovered. Normal budgeting arrangements at modest levels have enabled continuance of most programmes. All financial licence commitments for the entire term of the licence to 1992 have already been fulfilled.

Two programmes were reported to be in progress at May 1990; seepage search - and some analysis, and seismic data testing. Other programmes (including regional stratigraphic/palaeontology compilation and regional interpretation of gravity and magnetic data) are now also underway.

Work proposed was designed to

- 1 permit finer resolution of issues already defined in the area south of Hobart and perhaps provide for well targeting.
- 2 provide a regional understanding of the area north of Hobart which is commensurate with that now extant for the southern area,
- 3 pinpoint any seepage concentrations anywhere in the expanded licence in order to confirm petroleum geochemistry and perhaps suggest foci for detailed exploration.

A reduced on-going program has maintained these objectives in so far as was possible. Data is now available which allows 1 and 2 and some areas indicated by previously reported seep searches have been analysed in some detail.

Seepages and geochemistry:

Seepages continue to be reported from diverse locations in Tasmania, some within EL 1/88 and some beyond it. Work during 1990 (Appendix 2) has established the existence of up to four MATURE oils of probable pre-Carboniferous origin. Source and possible reservoir rocks for some of these oils occur in the upper part of the Ordovician Gordon Group.

Geochemical studies are continuing in order to better define sources.

Geophysics:

No new data were acquired during the past year.

A combined gravity and magnetic interpretation of existing data has been commenced. At the time of writing only a regional setting for the entirety of the licence area and a local analysis of the Derwent Valley have been completed.

The regional study has enabled refinement of general concepts to be tested and a revised version of the mantle separation process to be produced. The analysis upon which the latter is based includes consideration of large scale crustal features, including granites and major crustal breaks, but the result allows a higher ultimate resolution in interpretation of gravity anomalies. This result is important since it allows extended use of the gravity survey data; crucial to area appraisal in the absence of large scale seismic surveys.

The analysis to date has confirmed earlier indications of thrust stacking of the Palaeozoic rocks beneath central Tasmania. It appears that the basal thrust may lie within the dolomitic rocks of Upper Precambrian age. These units and all above them have been repeated several times. Rocks of Mathinna Beds affinity appear to have been included in this structuring across at least half of the island. A NE-SW compression is implied for the youngest stack with movement from the northeast. Granites have intruded the entire structural pile.

Magnetic data outlines the architecture of the structural patterns, defines some of the shallow expressions of the structures, and indicates the presence of Cambrian rocks within individual blocks. Identification of such sequences will prove an aid to future delimiting of Ordovician rocks.

Seepage sites can be positively associated with identifiable trends or interpreted structures. Analysis is being continued and accelerated.

Further seismic data analysis has been completed by the Bureau of Mineral Resources but this has not proved as effective as work done by the Shell Oil Co. Lines in the Storm Bay area clearly reveal large deep seated faults

and clear evidence of mid section thrusting which has introduced strong reflectors at about 2 seconds. Further analysis is being undertaken and the procedures will now be applied to all lines. Details will be provided when released by Shell.

A progress report describing preliminary gravity and magnetic analysis has already been submitted.

Conductivity data from the northern midlands continues to be acquired and analysed as part of University research projects. This will be collated and reported in due course.

Implications:

The broad distribution of established seepages across onshore Tasmania and the suggestion that most, if not all, are sourced from rocks older than Devonian in age suggests a much broader source rock distribution than might have been suspected by inspection of a surface geological map which displays large tracts of Precambrian rocks. Yet some of these have been weeping hydrocarbons!

The association of the regional geophysical trends with the seepage distribution as now known and the previously inferred relationship between sightings and seismic activity early this century also indicates that the surface geology is misleading.

For several years past I have argued, for example in many Mt Read Volcanic Project Reports commissioned by the Mines Department, that large areas have been detached and overthrust. I have since argued (Banks Symposium, 1990) that all Precambrian blocks have been displaced and re-arranged. Some movements may involve the whole crust while most are thin skin tectonic slices.

The distribution of hydrocarbons indicates that the thrust stack, in true alpine style, also incorporates source rocks. All parts of the state may include them although the zone between Cradle Mountain, Great Lake and Bothwell may not. This has yet to be confirmed.

The ramifications are far reaching and multiply the play possibilities as well as complicating evaluation and interpretation.

It is likely that Conga Oil will deal initially with the simpler categories of possible targets unless other indicators suggest other options may prove more fruitful.

PROGRESS FROM MAY 1990 TO DATE:

1. Further seepage sites have been added to existing compilations.
2. Representative samples have been analysed; in particular those from the Midlands and Preolenna areas.
3. Geochemical work has now confirmed the existence of several distinct hydrocarbon compositions
4. Regional (statewide) interpretation of the gravity and magnetic data has been begun and a new gravity crustal model produced. This has been used to update maps of the residual gravity field across Tasmania.
A preliminary report describing initial combined interpretation of the Midlands has been submitted. This included a more detailed study of the Derwent Valley region.
Work is continuing.
5. Marine seismic data have been reprocessed, including restacking, and will also be migrated. Results are yet to be finalised by Shell before presentation to Conga Oil.

PROGRAMMES IN PROGRESS:

1. The seep search programme directed toward identification of as many sites as possible is being continued. It is hoped that particular site concentrations or patterns will assist initial drill targeting or focus for geophysical analysis and perhaps trial seismic survey.

2. Seismic processing tests (per Shell research division) are nearly complete.
3. Gravity and magnetic interpretation focussed upon zones with the most seepage sites is in progress and the current phase of work should be complete by early July.

PROGRAMMES PROPOSED:

1. Extension of the gravity and magnetic interpretation.
2. Public assisted seepage search. It is hoped that this might lead to reasonable sample volumes and confirmation of source and fluid signatures. Geochemical work to continue in association with the search.
3. Further onshore seismic trials. Since it is clear that any well programme may be limited or forced toward purely stratigraphic objectives in the absence of specific structural controls the problems related to seismic data acquisition must be resolved. Only the coupling of gravity- magnetic implications with seep concentration foci and local seismic survey will lead to viable targetting. Any decisions about further surveys will be taken once specification and processing requirements have been established by the research still in progress.
4. Selection of two sites for stratigraphic diamond drilling of pre-Permian sections. It is expected that the sites chosen will test concepts and sections developed during the present interpretation.
5. Appraisal of areas to be relinquished in June 1992.

SUMMARY OF EXPLORATION OBJECTIVES

Recent work has demonstrated that the region has petroleum potential and must be explored.

The presence of Ordovician or other Lower Palaeozoic - sourced hydrocarbons means that the so-called Tasmania Basin can no longer be considered a post Permian backwater with no potential.

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 defined upon analysis of such seepages will be critical. It is hoped that these indicators might be tied to inferred lithological or structural distribution; as suggested from the geophysical or pyroclastic studies.

Although present work is incomplete there appears to be considerable spread in potential seepage sites. This is most encouraging but the distribution, structural analysis and seismic data now available indicate that the source units are repeated in an alpine thrustal stack.

PLAY DEFINITION:

Preliminary work to date suggests the possible presence of fold closures, rejuvenated troughs, unconformity seals, thrust 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 (although optimum specifications have yet to be defined) 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).

The simpler trap styles listed above may not warrant the principal effort. The concept of a thrustal stack increases the target options and exploration problems while offering the possibility for some larger plays. All styles must be reviewed.

0005

5

OVERALL:

To evaluate the region in such a way as to rationally assess its potential for Conga's purposes or to aid future explorers and enable reasonable relinquishment decisions within the next year.

EXPENDITURE SUMMARY

The table below summarises expenditure for the past year.
The figures, and categorisation, quoted above are as supplied to me by the financial manager of Conga Oil. A complete breakdown is available from the company ledgers.

The table below summarises expenditure for the past year.

Geology (appraisals and seep search)	41105
Geochemistry (analyses etc)	7000
Geophysics (interpretation)	33266
Drilling	0
Administrative overheads	35281
Other (consultants-displays-staff)	31358
Total	148010

Total of previous expenditure as reported in May 1990 was \$303327.

Total of all expenditure to May 1991 is thus \$451 337

Note: The above total expenditure exceeds the minimum required expenditure required under the terms of the licence for the initial three year term.

Report submitted on behalf of Leaman Geophysics by



Dr. D.E. Leaman, B.Sc., Ph.D.,
F.Aus.I.M.M., M.M.I.C.A

0006

APPENDIX 1:

RECENT DEVELOPMENTS IN EXPLORATION FOR OIL IN TASMANIA

by M.R. Bendall¹, J.K. Volkman², D.E. Leaman³ and C.F. Burrett⁴

Recent work on oil seeps, organic geochemistry, geophysics, structural geology and palaeontology suggests that there is considerable potential for onshore petroleum exploration in Tasmania.

Archival research has shown that hydrocarbon seeps were commonly reported in the first half of this century and that wildcats produced gas (at Port Sorell in the north) and oil (at Johnsons Well on Bruny Island, in the south). Almost all of the 270 historical hydrocarbon occurrences lie on lineaments revealed independently by gravity and magnetic surveys. The thermal maturity of conodonts from Ordovician and Siluro-Devonian carbonates suggests that much of the pre-Upper Carboniferous beneath the Tabberabberan unconformity is in the oil and gas windows.

Organic geochemistry reveals a very close similarity between hydrocarbons from Ordovician limestones, those from the drill site at Bruny Island and with tar samples from the Tasmanian coast but little similarity with the Permian Tasmanian Oil Shale, or with the botryococcane-rich Gippsland-Otway-Bass crude and South Australian bitumens. The predominance of C₂₇ steranes suggests a widespread algal source and the abundant diasteranes imply a clay or silt rich source rather than a carbonate source that extends across the whole of Tasmania.

Recent geophysical and structural work suggests that a thin skinned interpretation of Tasmania's structure is reasonable. Most sightings of hydrocarbons are associated with either faults or fractures which have post-Jurassic displacements or with intersections of major high angle faults with thrusts.

The delineation of reservoirs within the thrust sheets is a priority.

INTRODUCTION

Tasmania has been considered unprospective for hydrocarbons for over 50 years. This view has resulted from misunderstandings or ignorance about the nature and origin of the many occurrences of hydrocarbons previously recorded. Oil shales of Permian age have long been known and some production has been derived from them.

The numerous records of seepage or tar sightings from the period 1880-1935 have been ascribed to an oil shale source. The absence of serious exploration in recent times has led to general ignorance of the existence of these records. Modern maps of Australian basins refer to the "Tasmanian basin" when considering Tasmania. This is taken to mean the late Carboniferous-Triassic deposition presumed to overlie uneconomic basement.

Consequently, if it is assumed that any hydrocarbons present were derived from Permian oil shale then no reliable seals or traps of any magnitude are likely due to disruption of the post-Carboniferous sequences by faulting and intrusion and an absence of closed structures. An unprospective environment is a valid conclusion on these assumptions.

Many pre-war observers were not of this view since many seepage sites are far removed from Permian rocks and several occur in Precambrian quartzite (Port Davey) or Precambrian granite (King Island). Many are directly associated with Ordovician carbonates, or such rocks occur nearby. They could not, however, offer a credible explanation for these occurrences.

The lack of exploration activity since 1939 may be contrasted with that of the previous 50 years when many companies were floated. All were based on effusive oil or tar seepages. Some accumulations were large; sufficient to fill the hold of a coastal cargo vessel (from Port Davey). Few drilling proposals were converted into action but several attempts were made to drill at Port Sorell and Bruny Island. The maximum depth of any such hole was about 400 m but gas was recorded in one well at Port Sorell and oil was recovered in small quantities from another at Bruny Island.

¹ Conga Oil Pty Ltd, 84 Wells Parade, Blackmans Bay, Tasmania 7152.

² CSIRO Division of Oceanography, GPO Box 320D, Hobart, Tasmania 7001.

³ Leaman Geophysics, GPO Box 320D, Hobart, Tasmania 7001.

⁴ Geology Department, University of Tasmania, GPO Box 252C, Hobart, Tasmania 7001.

M.R. Bendall, J.K. Volkman, D.E. Leaman and C.F. Burrett

This paper presents information assembled during the last 10 years, and especially the last three years. It suggests that the faith of the early explorers was well based and that the perceptions of the last 50 years have been wrong. Hydrocarbon occurrences have been verified, are widespread and are associated with seismic activity. The chemistry of the seep hydrocarbons is not consistent with Permian oil shale derivation but is indicative of lower Paleozoic source rocks. This knowledge, when coupled with a revised structural view of Tasmania, transforms prospectivity assessments.

GEOLOGICAL HISTORY

A full and recent account of the geology of Tasmania may be found in Burrett and Martin (1989). The oldest rocks in Tasmania (Fig. 1) are Proterozoic quartzites, phyllites and dolomites which crop out extensively in the central and northwestern parts of the island. After the Penguin Orogeny at 750 Ma these were unconformably overlain by shallow marine quartz sandstones and dolomites and then by marine turbidites, mudstones and basalts in the late Proterozoic or early Cambrian. A mineral-rich island arc (Mt Read Volcanics)-back arc basin (Dundas Group) complex formed in the middle to late Cambrian and was unconformably overlain by turbidites and volcanoclastics in the latest Cambrian. These mainly marine sediments were successively overlain in the Ordovician by fanglomerates (Owen Conglomerate and correlates), by shallow marine sandstones (Moina Sandstone and correlates), by subtidal siltstones and mudstones (Florentine Valley Mudstone and correlates) and by a thick succession of tropical carbonates (Gordon Group). The Gordon Group carbonates are up to 1.5 km thick in central Tasmania and are dominantly micritic. Dolomitisation is common. In the south there is a transition southwards from shallow marine conditions near Vanishing Falls, to platform margin buildups at Precipitous Bluff to deep (>200 m) water carbonate turbidite-graptolitic shale environments at Surprise Bay (Burrett et al., 1981, 1983, 1984). The Gordon Group carbonates were conformably overlain by the dominantly marine siliciclastics of the late Ordovician–Early Devonian Eldon Group. In the eastern third of the state, Ordovician–Devonian sediments consist of graptolitic basinal turbidites (Mathinna beds).

The Tabberabberan Orogeny in the Early Devonian created a fold-thrust belt producing approximately north-south trending folds in most areas but with east-west trending folds in the northwest of the state. Numerous and extensive granitoids were intruded between 395 and 320 Ma. Regional metamorphism gave rise to the pattern of conodont CAI (Colour Alteration Index) isograds shown in Figure 2 with heating of the lower Palaeozoics to 300°C in the west and northwest with much lower temperatures (150°C) in central and southern Tasmania (Burrett, in press). In the late Carboniferous–Permian, a sequence of glacialterrestrial and glacialmarine predominantly siliciclastics

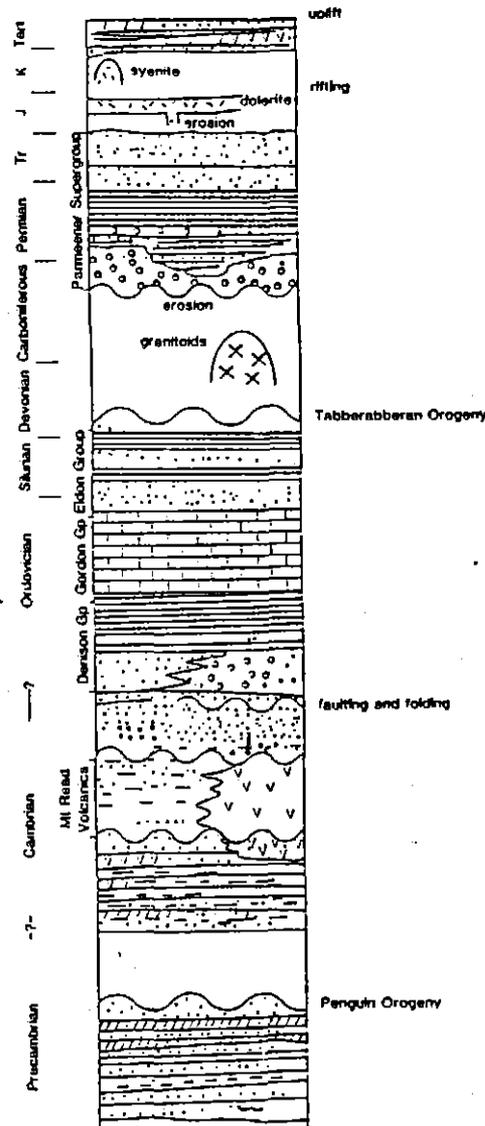


Figure 1— Highly generalised geological column for Tasmania.

(lower Parmeenian Supergroup) were deposited unconformably on the older rocks and succeeded conformably by Triassic terrestrial sandstones of the upper Parmeenian Supergroup. Coals are present in both divisions of the Parmeenian and the famous Tasmanite Oil Shale occurs just above the basal tillite of the supergroup.

Extensive, thick (often 500 m) sills of dolerite fed by narrow feeder dykes were intruded in the middle Jurassic and presently outcrop over about half of the state. Although the dolerite is voluminous, metamorphism appears to be restricted to the immediate vicinity of the sheets. Minor local syenites were intruded in the Cretaceous but regional heating was sufficient to reset the Palaeozoic palaeomagnetism. North to northwesterly trending horst and graben were produced in a general tensional environment in the late Cretaceous to early Tertiary and the graben were filled with up to 1 km of mainly terrestrial sediments. Many onshore Tertiary volcanic centres are present.

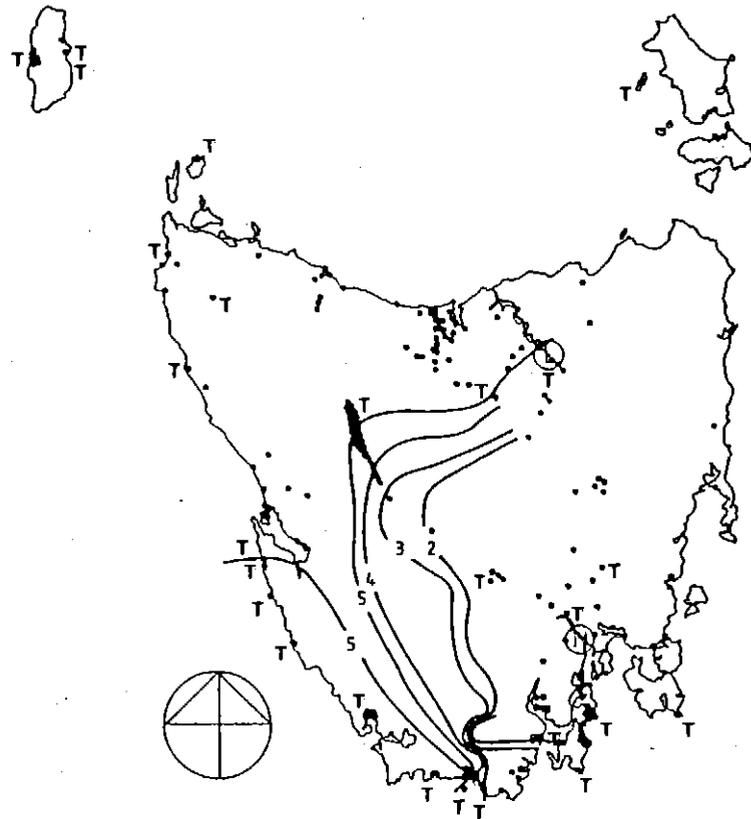


Figure 2 — Seep distribution in Tasmania from Bendall (1990). T = tars. Contour lines are isograds based on conodont Colour Alteration Indices (CAI) from Burrett (in press). CAI 5 = 300°C and CAI = 100°C.

SEEP DISTRIBUTION AND ORGANIC GEOCHEMISTRY

Seeps

The distribution pattern and historical background of seeps are summarised by Bendall (1990). The distinctive NW/SE, NE/SW seep trends (Fig. 2) transect all rock types strongly suggesting that deep crustal lineaments are still active. Seepages have been reported mainly, directly after major quakes. The records from archival research include 35 drill holes, 127 oil leases and 120 signs of either tar, oil or gas. The discovery of some of the recorded tars in Launceston's museum, along with archived photographs confirm the validity of the old records. Geochemical confirmation of hydrocarbons around the 1929 Bruny Island drill hole, current gas seeps at that site and wet gas recently found at Dunalley are all on lineaments and suggest the validity of other unconfirmed sightings on those lineaments. Many companies were formed to exploit the potential that the seeps indicated (Bendall, 1990).

Of these companies only two produced shows of hydrocarbons both of which were confirmed by government geologists, as were many of the historical reports of tars and seeps.

Organic Geochemistry

Methods

Sediment from the site of the 1929 drilling at Johnsons Well on Bruny Island was extracted with hexane with ultrasonication. Solvents of greater polarity were not used due to the high concentrations of naturally occurring polar lipids. The limestone sample from Ida Bay in southern Tasmania was crushed and then a portion was extracted using chloroform-methanol with ultrasonication. The bitumen from Port Davey in western Tasmania was extracted directly with chloroform, which dissolved the entire sample. Portions of each extract were analysed by Jaroscan thin-layer chromatography-flame ionisation detection (Volkman et al., 1986) to determine the total hydrocarbons.

Saturated and aromatic hydrocarbons were isolated by applying a portion of the extract to a column of silicic acid capped with activated alumina. Aliphatic hydrocarbons were eluted with hexane and a second fraction containing aromatic hydrocarbons was obtained by eluting with toluene:hexane. Resins and asphaltenes were eluted with chloroform and methanol.

Each hydrocarbon fraction was analysed by capillary

M.R. Bendall, J.K. Volkman, D.E. Leaman and C.F. Burrell

gas chromatography on a non-polar methyl silicone fused silica capillary column to determine the distribution of straight-chain and isoprenoid alkanes. These fractions were then analysed by gas chromatography-mass spectrometry in selected ion monitoring mode (SIM) (Volkman et al., 1988). Ion chromatograms for ions m/z 217 and 218 (steranes), m/z 259 (diasteranes), m/z 231 (methyl steranes), m/z 191 (hopanes and other triterpanes), m/z 177 (demethylated hopanes), m/z 205 (methyl hopanes) plus some molecular ions were acquired.

Results

Geochemical analyses of two soil samples from Johnsons Well were undertaken. These revealed small amounts of hydrocarbons (about 400 ng/g) which were dominated by *n*-alkanes of plant origin, plus the common petroleum constituents pristane and phytane (ratio 2.1). GC-MS fingerprinting conclusively demonstrated the presence of trace amounts of petroleum hydrocarbon biomarkers including steranes and diasteranes (Fig. 3) and hopanes (Fig. 4). Trace amounts of petroleum-derived hydrocarbons were also detected in a few water and sediment samples from elsewhere on the island, but the amounts were generally too low for detailed fingerprinting studies. The low concentrations of petroleum-derived hydrocarbons indicated that petroleum seeps were no longer active at this site but provided some evidence for their former presence.

A limited organic geochemical study was undertaken of the hydrocarbons in Ordovician limestones from Ida Bay in southern Tasmania and Queenstown in the west. One sample from Queenstown was of interest as it appeared to contain flecks of asphaltic material. These rocks contained low amounts of hydrocarbons (2.9 mg/g at Ida Bay and 0.8 and 1.2 mg/g at Queenstown), but the distributions were typical of those found in mature petroleum. Although sediments from the Queenstown area have much higher conodont CAIs (Fig. 2), which suggest a higher thermal maturity, the biomarker maturity parameters in samples from the two regions were remarkably similar.

The sterane distributions in the limestones showed many similarities to those in the Johnsons Well soil sample. In particular, the ratios of $C_{27}:C_{28}:C_{29}$ steranes, which is a useful source parameter (Mackenzie, 1984), were almost identical. Similar ratios have been found in carbonate-derived oil from the Middle East, and from Ordovician sediments from mainland Australia (Hoffmann et al., 1987). However, this ratio is very different from those found in oils presently recovered from the Gippsland Basin which show a strong predominance of C_{29} steranes. The presence of similar amounts and proportions of rearranged steranes (diasteranes) was also of interest since these compounds are usually of very low abundance in pure carbonates.

In 1990, 15 samples of bitumens collected early this century from coastal sites were obtained from Tasmanian museums for geochemical analysis. Many of these samples are mentioned in a report on petroleum exploration in

Tasmania (Twelvetrees, 1917). All the samples are black, shiny asphaltic bitumens which show a characteristic conchoidal fracture and a naphthalatic odour when broken. They contain no inorganic matter and dissolve completely in chloroform.

Aliphatic hydrocarbons represented 13.2–15.0% of the total extract of the bitumens, aromatic hydrocarbons 3.9–6.7%, with the remainder consisting of polar resins and asphaltenes. The distributions of aliphatic hydrocarbons in each bitumen were similar to those of mature crude oils except that volatile hydrocarbons ($<n-C_{10}$) were absent. The *n*-alkanes extended at least to *n*- C_{35} with no odd or even predominance. Higher molecular weight components were not abundant indicating that the bitumens are not derived from the type of waxy crude more commonly associated with Gippsland Basin crudes. The major *n*-alkane was either *n*- C_{16} or *n*- C_{18} . Pristane and phytane were the most conspicuous branched constituents in all samples. Longer-chain isoprenoids were comparatively minor components and botryococcane, which occurs in some bitumens found on South Australian beaches (McKirdy et al., 1986), was not detected. The pristane/phytane ratios of most samples fell in the range 1.30–1.38. All of the chromatograms showed a small "unresolved complex mixture" (UCM or hump) throughout the chain-length range typical of crude oils. The aliphatic hydrocarbon distributions gave the overall impression of a non-waxy, weathered heavy crude oil.

GC-MS fingerprinting showed that the sterane distributions in all of the bitumens were remarkably similar. The Port Davey sample is typical (Figs 3 and 4). Although C_{27} steranes (peaks 5, 7, 8 and 9) predominate, they are only slightly more abundant than the C_{29} steranes and C_{28} steranes. This feature is also found in hydrocarbons isolated from the Ordovician limestone samples and the soil from Johnsons Well (Fig. 4). The bitumens also contain significant amounts of diasteranes. Mass fragmentograms for m/z 231 showed that small amounts of methyl steranes were present in all the bitumens, but individual compounds were not identified (data not shown).

The distributions of hopanes were characterised from mass fragmentograms of the major fragment ion m/z 191 (Fig. 4). Comparable data for the hopanes isolated from the Johnsons Well and Ida Bay samples are also shown. The major hopane peak in the bitumens was C_{30} , with C_{29} next most abundant. Moretanes were present in low abundance (peaks 6, 9 and 12), and the ratios of 22S to 22R epimers in the extended hopanes (i.e. $>C_{30}$; e.g. peaks 10 and 11) were typical of a mature oil. These isomers isomerise to an equilibrium mixture before the onset of the oil window. The ratio of the two C_{27} hopanes Ts (peak 1) and Tm (peak 2) is a sensitive indicator of thermal maturity. Ts was less abundant than Tm in all samples implying that all bitumens were generated at closely similar thermal maturities at an equivalent vitrinite reflectance of about 0.6–0.7.

Although the sterane distributions in the Johnsons Well, Ida Bay limestone and bitumen samples were all very

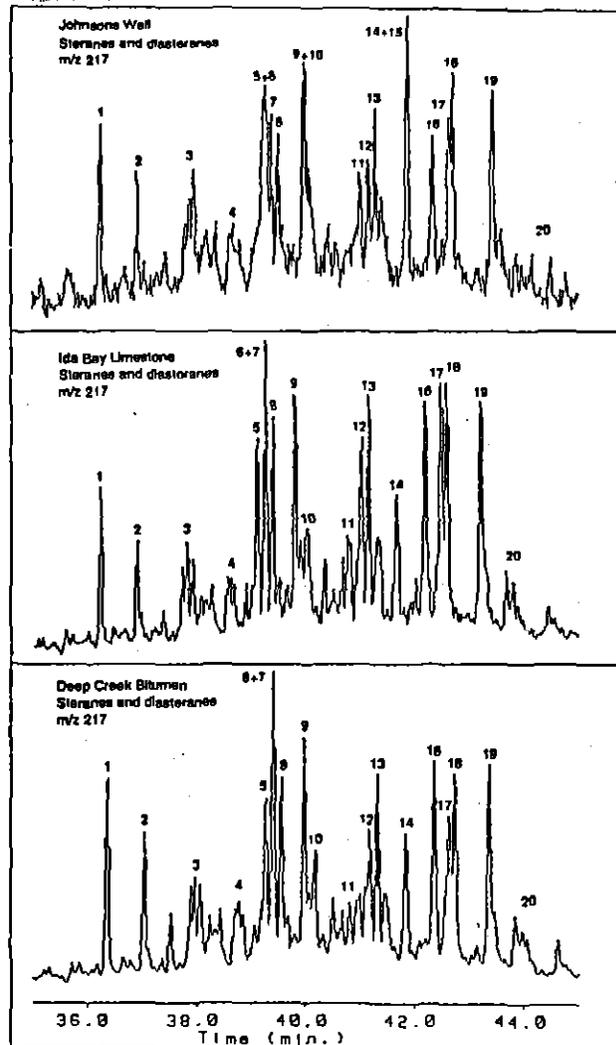


Figure 3 — Mass fragmentograms for m/z 217 showing distributions of C27-C30 steranes and diasteranes in (a) soil from Johnsons Well on Bruny Island, (b) Ordovician carbonate from Ida Bay and (c) tar from the mouth of Deep Creek near Port Davey on the west coast of Tasmania. Compound identifications are identifications of peaks in m/z 217 mass fragmentograms.

Peak	Steranes and diasteranes	
1	C27	(20S)-13 β (H),17 α (H)-diasterane
2	C27	(20R)-13 β (H),17 α (H)-diasterane
3	C28	(20S)-13 β (H),17 α (H)-diasterane
4	C28	(20R)-13 β (H),17 α (H)-diasterane
5	C27	(20S)-5 α (H),14 α (H),17 α (H)-cholestane
6	C29	(20S)-13 β (H),17 α (H)-diasterane
7	C27	(20R)-5 α (H),14 β (H),17 β (H)-cholestane
8	C27	(20S)-5 α (H),14 β (H),17 β (H)-cholestane
9	C27	(20R)-5 α (H),14 α (H),17 α (H)-cholestane
10	C29	(20R)-13 β (H),17 α (H)-diasterane
11	C28	(20S)-5 α (H),14 α (H),17 α (H)-24-methylcholestane
12	C28	(20R)-5 α (H),14 β (H),17 β (H)-24-methylcholestane
13	C28	(20S)-5 α (H),14 β (H),17 β (H)-24-methylcholestane
14	C28	(20R)-5 α (H),14 α (H),17 α (H)-24-methylcholestane
15		Unknown
16	C29	(20S)-5 α (H),14 α (H),17 α (H)-24-ethylcholestane
17	C29	(20R)-5 α (H),14 β (H),17 β (H)-24-ethylcholestane
18	C29	(20S)-5 α (H),14 β (H),17 β (H)-24-ethylcholestane
19	C29	(20R)-5 α (H),14 α (H),17 α (H)-24-ethylcholestane
20	C30	24-propylcholestanes

M.R. Bendall, J.K. Volkman, D.E. Leaman and C.F. Burrett

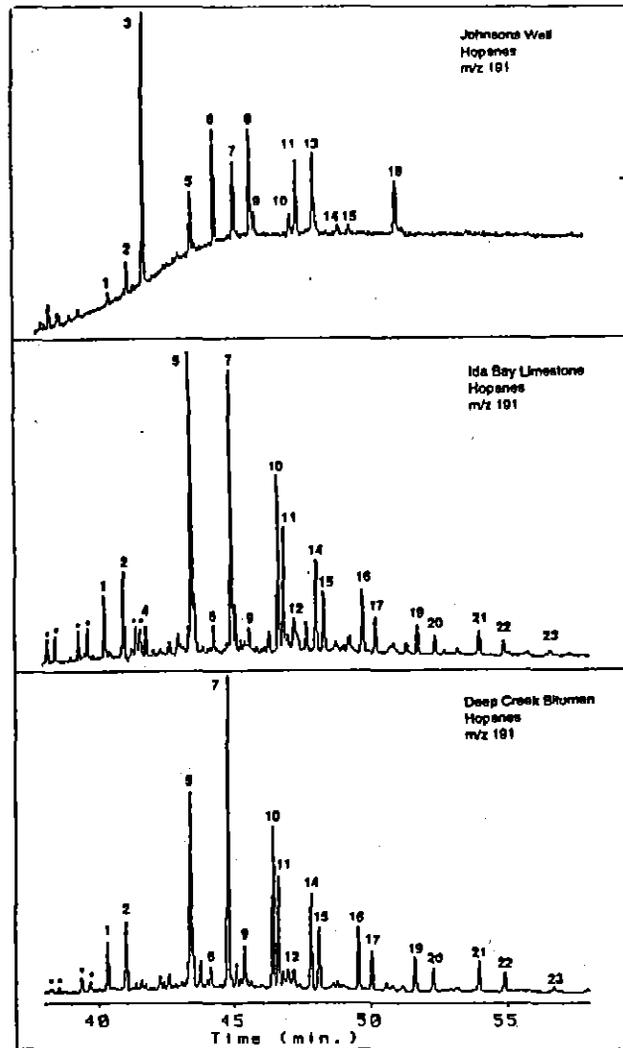


Figure 4 — Mass fragmentograms for m/z 191 showing distributions of C_{27} - C_{36} hopanes in (a) soil from Johnsons Well on Bruny Island, (b) Ordovician carbonate from Ida Bay and (c) tar from the mouth of Deep Creek on the west coast of Tasmania. Tricyclic alkanes are denoted by *. The baseline rise in mass fragmentogram (a) is due to a contribution of the m/z 191 ion from column bleed. Identifications of peaks in hopane (m/z 191) and methyl hopane (m/z 205) mass fragmentograms:

GC-MS Peak	Hopane	GC-MS Peak	Hopane
1	C_{27} 18 α (H)-22,29,30-trisnorhopane (Ts)	13	C_{30} 17 β (H),21 β (H)-hopane
2	C_{27} 17 α (H)-22,29,30-trisnorhopane (Tm)	14	C_{32} (22S)-17 α (H),21 β (H)-bishomohopane
3	C_{27} 17 β (H)-22,29,30-trisnorhopane	15	C_{32} (22R)-17 α (H),21 β (H)-bishomohopane
4	C_{28} 17 α (H),21 β (H)-29,30-bisnorhopane	16	C_{33} (22S)-17 α (H),21 β (H)-trishomohopane
5	C_{29} 17 α (H),21 β (H)-30-norhopane	17	C_{33} (22R)-17 α (H),21 β (H)-trishomohopane
6	C_{29} 17 β (H),21 α (H)-30-normoretane	18	C_{31} (22R)-17 β (H),21 β (H)-homohopane
7	C_{30} 17 α (H),21 β (H)-hopane	19	C_{34} (22S)-17 α (H),21 β (H)-tetrakishomohopane
8	C_{29} 17 β (H),21 β (H)-30-norhopane	20	C_{34} (22R)-17 α (H),21 β (H)-tetrakishomohopane
9	C_{30} 17 β (H),21 α (H)-moretane	21	C_{35} (22S)-17 α (H),21 β (H)-pentakishomohopane
10	C_{31} (22S)-17 α (H),21 β (H)-homohopane	22	C_{35} (22R)-17 α (H),21 β (H)-pentakishomohopane
11	C_{31} (22R)-17 α (H),21 β (H)-homohopane	23	C_{36} (22S)-17 α (H),21 β (H)-hexakishomohopane
12	C_{31} (22R+S)-17 β (H),21 α (H)-homomoretane		

similar, the hopane distributions showed significant differences. The hopanes in the limestones contained significantly more C_{29} hopane due to the presence of a series of 29-norhopanes which were not present in detectable amounts in the bitumens. The bitumen hopane distributions are more typical of those found in shales. The carbonates also contained a series of C_{28} - C_{36} 2-methylhopanes, whose mass spectra have a characteristic base peak at m/z 205. These compounds were trace constituents of the bitumens, implying that the bitumens were unlikely to be derived from a carbonate source rock. C-10 demethylated hopanes were not detected in any of the samples using m/z 177 mass fragmentograms. These compounds are commonly associated with highly biodegraded residues of crude oil (Volkman et al., 1983), which suggests that the bitumens are not simply tar residues from exposed reservoirs.

The hopane distributions in the Johnsons Well sample do not, at first sight, appear to be at all related to either the Ida Bay carbonates or to the bitumen samples. This is due to a predominance of hopanes from microorganisms in the soil. Several of these hopanes have 17b(H),21 β (H)-stereochemistry (peaks 8, 13 and 18) which is typical of biologically-produced hopanoids. This complication must always be considered when attempting to fingerprint petroleum-derived hydrocarbons in soil or in geologically young sediments (Volkman et al., 1988). However, hopanes of obvious petroleum origin such as Ts, Tm and extended hopanes were present. 2-Methylhopanes were not detected which rules out Ordovician carbonates as the source.

The remarkable similarity between all the sterane distributions implies that the hydrocarbons in the bitumens are probably derived from the same type of organic matter which contributed to the carbonates. The predominance of C_{27} steranes is not found in oils generated from higher plants or from coaly matter, but is more typical of algal matter. The presence of abundant diasteranes implies a depositional environment in which the sediments contain a high content of silt or clay. The absence of methyl hopanes argues against a shallow carbonate depositional environment.

The very low abundance of tricyclic alkanes in the bitumens indicates that the Tasmanite Oil Shale, in which these compounds are the pre-dominant biomarkers (Denwer, 1986; Simoneit, 1986), was not the source of these hydrocarbons. Also, the oil shales show a much higher predominance of C_{29} steranes and a very different diasterane/sterane ratio (Denwer, 1986). Moreover, the maturity of the hydrocarbons in the bitumens is significantly greater than that found in Tasmanite Oil Shale.

The geochemical data imply the existence of a source rock and reservoirs extending over much of present-day Tasmania and adjacent near-shore areas.

GEOPHYSICS AND STRUCTURE

Any suggestions that the historic and modern hydrocarbon occurrences might be derived from Lower Paleozoic source

rocks and that reservoir potential might exist in the rocks beneath the unconformity at the base of the Upper Carboniferous-Triassic "Tasmania basin" rocks known as the Parmeener Supergroup pose problems for conventional models of Tasmanian geology. The pre-Parmeener rocks are concealed across more than half of Tasmania and the proposed source and reservoir rocks are never the dominant materials exposed elsewhere. Much of Tasmania consists of exposed Cambrian and Precambrian in the west and the Ordovician-Devonian turbidites in the northeast — all intruded by Devonian granitoids — and these have been inferred to occur at shallow depth beneath the unconformity. The few drill holes to have penetrated pre-Parmeener basement have proven dolomitic Precambrian, turbidites or Cambrian volcanics. No hole is deeper than about 1000 m and all have been drilled for stratigraphic evaluation of the lower Parmeener.

Yet the seepages are widespread and possibly systematic.

Conga Oil began exploration on Bruny Island in southern Tasmania. No pre-Parmeener rocks are exposed for more than 30 km in any direction, although drilling had proven Precambrian rocks at 999 m at nearby Woodbridge and Cambrian volcanics at 600 m beneath the northern suburbs of Hobart. Appreciation of the local issues and significance of the 1929 drilling finds depended first on structural removal of the dolerite, stripping of the Parmeener cover and assessment of the likely composition and distribution of material beneath the unconformity.

Gravity and magnetic methods have a long and proven record for structural assessment (e.g. Leaman and Richardson, 1981) in this complex surface environment and have formed the basis for all deep appraisal.

Gravity and Magnetic Surveys

Because of their cost effectiveness and their ability to reveal shallow structures and dolerite forms, gravity and magnetic surveys were extended from the area of the Bruny Island hydrocarbon occurrence to central Tasmania.

The gravity coverage has taken the form of an infilling of the state gravity data base such that the nominal station spacing is about 2.5 km. All stations were fully corrected, including 22 km radius terrain corrections and were reduced using a crustal reference density of 2.67 t/m².

The aeromagnetic surveys were flown at elevations of 1000 and 1600 m for the southern and northern areas respectively with line spacings of 2.5 and 5 km. All specifications have been directed at resolution of primary structures and relationships at depths of 1000-5000 m below meter or sensor.

Details of the southern survey and its interpretation have been discussed by Leaman (1990). Interpretation of the northern survey remains incomplete although it is now known that structural styles inferred in the southern survey and which are comparable with those exposed in western Tasmania, persist across the island toward Bass Strait.

M.R. Bendall, J.K. Volkman, D.E. Leaman and C.F. Burrett

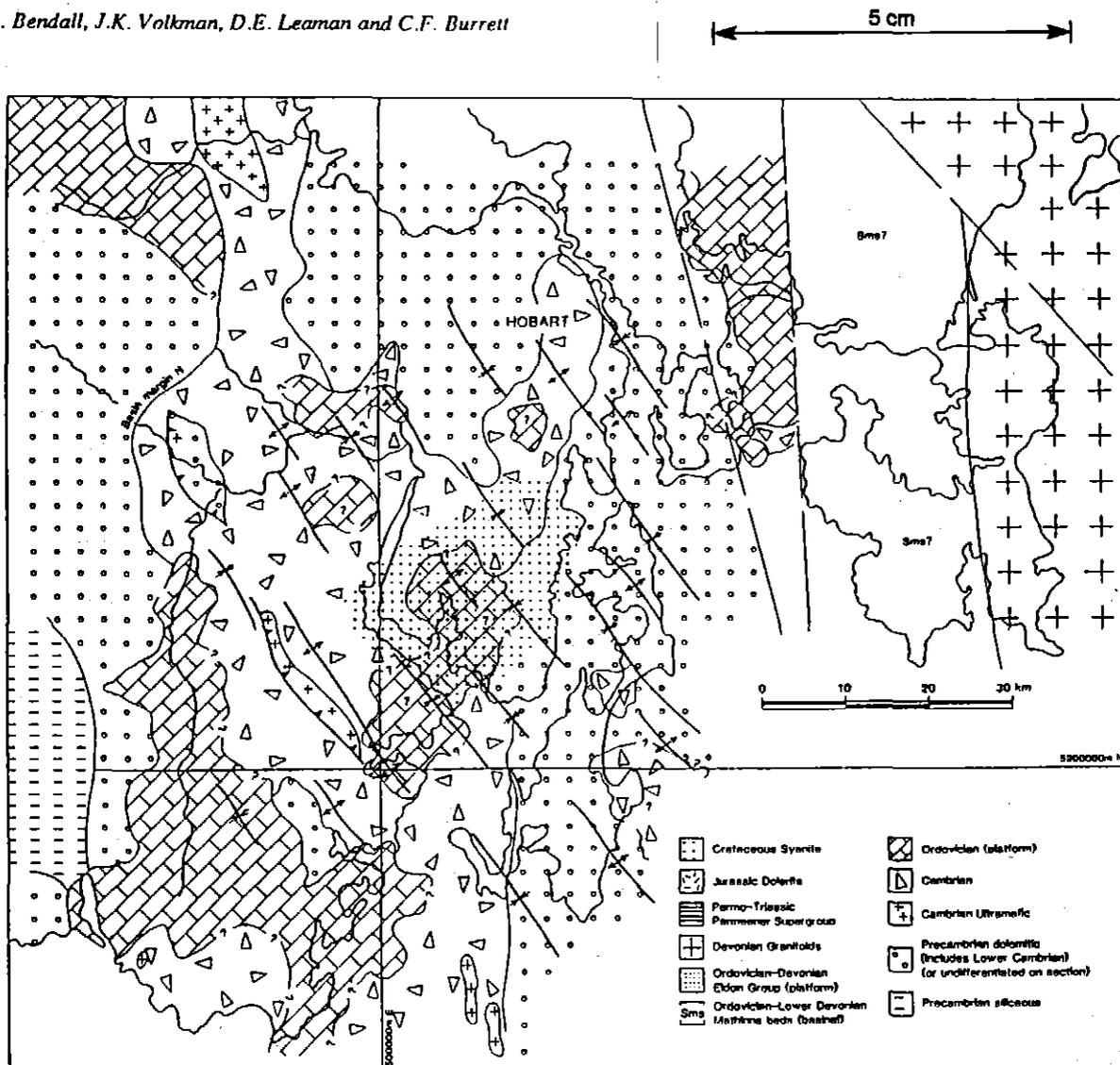


Figure 5 — Pre-Parmeener geological map of southeast Tasmania based on magnetic and gravity interpretations supplemented by sparse drillhole data.

The coupling of the two methods is essential to any minimum ambiguity resolution of concealed structures.

The surveys have revealed the presence of deep Cambrian troughs containing thick piles of mafic and intermediate volcanics. These troughs are commonly limited by major structures containing ultramafics. Interfaces within presumed Precambrian basement rock are also implied at depths which range from the sub-Parmeener unconformity to perhaps 4 km. Other Palaeozoic rocks overlap both Cambrian and Precambrian rocks and may be up to 2 km thick (in southern Tasmania). The presumed Ordovician and Silurian rocks can be traced to outcrops of the Gordon Group in the region west of Hastings or the Picton River. Figure 5 shows the geology as might be seen if the Parmeener and dolerite cover were stripped away.

Structure

The gravity and magnetic analyses have provided several geological revelations.

The Tamar Lineament, the fundamental crustal structure extending NNW-SSE across the island from the Tamar river to the southeast proposed by Williams (1979), is not supported by either data set. Magnetic trends are acute to the supposed structure.

The granites of eastern Tasmania are present as giant bodies elongated N-S and their western margin cuts across all types of basement geology (Leaman and Richardson, 1990). The granites of western and central Tasmania are relatively isolated but are sometimes large bodies (Leaman and Richardson, 1989).

Many structural and stratigraphic patterns are repeated. The important and recognisable units include the ultramafics of early-middle Cambrian age and thick dolomitic successions of latest Precambrian age. At least three major repetitions can be identified beneath the Parmeener. Similar repetitions have now been implied in western Tasmania where the same rocks are exposed. All parts of the lower Palaeozoic succession are involved.

Although relatively small scale thrusting has been recognised and mapped for many years large scale move-

ments involving basement or large portions of the Palaeozoic succession have rarely been accepted or proven. Leaman et al. (1973) reported the first demonstration based on gravity data and this has now been confirmed by mapping and structural review. Other instances have been recognised since acquisition of much data in western Tasmania as part of the Mt Read Volcanics Project (1985-). Examples of large scale basement and, occasionally, crustal involvement in thrust stacks have been given by Leaman (1986, 1987, 1988). Structures at Cape Sorell have now been established by drilling. Structures are complex; in western Tasmania the westward trending Devonian thrusts have disturbed pre-existing west facing early Cambrian thrusts.

Current interpretations suggest that little of the pre-Devonian geology of Tasmania, as presently exposed, is autochthonous.

Seismic Surveys

Very little seismic data are available for onshore Tasmania. A survey of Bruny Island was undertaken by Conga Oil in 1987.

Data records have been generally poor. This was initially ascribed to local terrain and surface high velocity problems. Jurassic dolerite produces irregular high velocity intrusion forms which couple with topographic effects to impose difficult static corrections. The dolerite also reflects much energy from its upper surfaces and apparent reflector shadows appear beneath. The base of a dolerite sheet is not generally reflected even though the velocity contrasts are large. Processing problems associated with such difficult data are presently being assessed. Offshore surveys in southern Tasmania by AMOCO in 1969 and by the Bureau of Mineral Resources in 1988, present characters very similar to land based surveys.

Both onshore and offshore surveys have recorded events, fragmentally, at times of 1-3 seconds. At Bruny Island, this event could be traced the length of the 7 km traverse at about 2 seconds. The implied depth of 3-4 km is consistent with the potential field inference of a major density contrast change from dense to less dense rocks.

Although most records appear bland for times in excess of 300 to 900 ms — the time depth of the base Parmeener unconformity in most cases — it has been possible to obtain excellent records to two-way times of 11 seconds at rare localities. One was reported near Clifton Beach south of Hobart (Leaman, 1978). Sites of this type suggest that seismic methods are viable when the entire Palaeozoic is present but that the bulk of the geology beneath the unconformity, for most of the areas sampled, is not strongly stratified and is, therefore, Cambrian or Precambrian.

Lineaments

The gravity and magnetic data sets define some spectacular lineaments (Fig. 6). An initial outline of these and their relationship to major tectonic elements was provided by Leaman and Richardson (1990).

DISCUSSION AND NEW PLAY CONCEPTS

Integration

Recent work has shown that the hydrocarbon sightings of the past century are likely to be reliable and that the hydrocarbons have been generated from lower Palaeozoic sources rather than from Permian oil shales. The sightings are reasonably systematic and the patterns are both statewide and correlate well with structural lineaments identified in gravity and magnetic data.

Comparison of sighting patterns and seismic activity in the Tasmania region suggests that hydrocarbons, as oil or tars, are generally observed in the period immediately following intense activity or occasional large earthquakes. A relatively quiescent period since 1957 has decreased release volumes and consequent reports.

Most sightings are associated with either faults or fractures which have post-Jurassic displacements or with intersections of major high angle faults with thrusts.

The evidence suggests that hydrocarbons have been, and perhaps still are being, generated and that the reservoir systems are either tight or well sealed. The thrust surfaces or the base Parmeener unconformity may act as sealing surfaces since the materials directly above them are either homogeneous quartzite and dolomitic siltstones or dense mudstones respectively.

All possible source rocks have yet to be analysed but hydrocarbons in southern Tasmania have been generated from the Gordon Group. The similarities and differences of seep analyses suggest hydro-carbon generation from at least three other lower Palaeozoic sources.

Reservoir conditions exist within the Ordovician carbonates where they were karsted after folding in the Early Devonian and before being overlain unconformably by Upper Carboniferous tillites. Primary porosities of 15% have been measured in Gordon Group carbonates and larger secondary porosities have been reported. Porosities of about 20% are known in some early Ordovician siliciclastics.

Play Concepts

Many possible play concepts may be envisaged.

Simple closed structures directly involving Ordovician and Silurian source and reservoir rocks may occur at the Parmeener unconformity where they are known to possess medium to long length closures (1 to 4 km) or beneath the major thrust surfaces. These materials may occur as thin residuals beneath the unconformity generally but may locally exceed 4 km in thickness where full sequences have been preserved. Thrust or unconformity seals are required.

Facies variations within the Gordon Group may also provide suitable trap conditions.

Many variations of these styles are possible but the most likely target category cannot be defined at the present time.

M.R. Bendall, J.K. Volkman, D.E. Leaman and C.F. Burrett

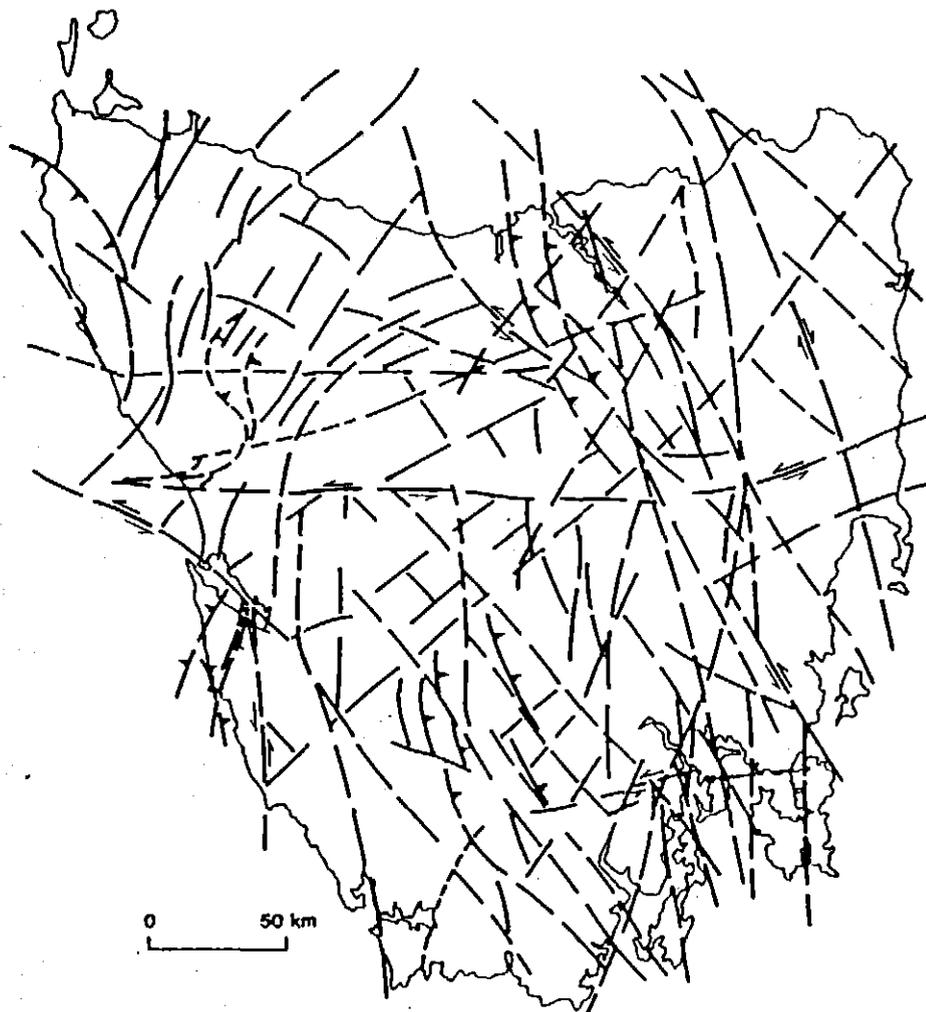


Figure 6—Major crustal lineations based mainly on magnetic and gravity surveys

5 cm

Figure 7 summarises the types of relationships and possible plays.

The principle exploration problems relate to the location and identification of target successions and possible structures within them. The gravity and magnetic data which have been extensively used to date have been able to define regional structural elements, infer the presence of target successions and suggest fold elements but are limited in ultimate resolution. Information recovered from these sources is sufficient to set viable stratigraphic targets — essential given the paucity of drilling control available — but not adequate for wildcat hydrocarbon proposals.

This will not be possible until more seismic data is available and the processing needs associated with it have been assessed and refined. Seismic tests can be specific since the potential field data have already defined general target locations. This is a cost-effective effective approach to the difficult problems presented by onshore Tasmania.

CONCLUSIONS

Recent appraisals of archived records, preserved tar samples, and structural construction of Tasmania have shown that:

- Most hydrocarbons recovered over many decades have been derived from Lower Palaeozoic rocks and not Permian oil shales.
- The source and reservoir conditions are largely concealed on an island-wide basis and that the exposed rocks, whether of the Carboniferous-Triassic Tasmania basin or the so-called Precambrian basement inliers, are irrelevant to prospectivity assessments.
- Tasmania must be seen as a typical fold-thrust province in terms of its hydrocarbon potential. Several major and minor thrusts are stacked. All Palaeozoic units are repeated and the entire overthrust system has been folded and intruded by granites. Precambrian basement inliers previously considered basement are blocks involved in

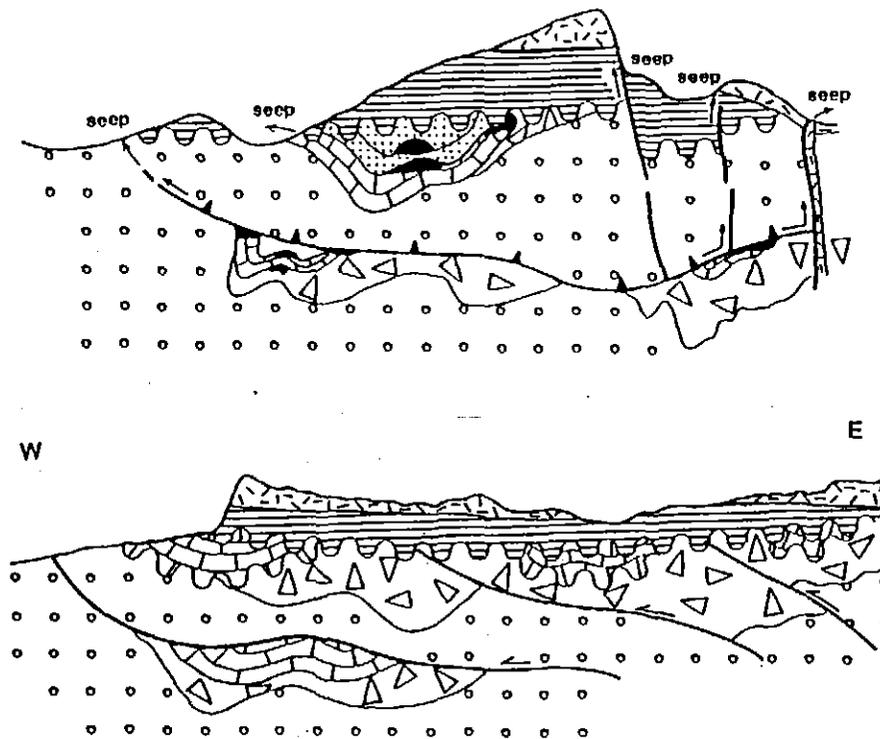


Figure 7 — Schematic cross sections showing play concepts in Tasmania. Reservoirs indicated by solid shading. Legend as for Figure 5.

the thrust stack. Devonian thrusting has been from east to west.

- Hydrocarbons have been produced in some quantity but are well sealed. Observations of released material have only been made after intervals of intense seismic activity.

ACKNOWLEDGEMENTS

We thank Glen Neill and Teresa O'Leary for their valued assistance with extractions and GC and GC-MS analyses and Izzy Herzog and Michael Lasky for their support.

REFERENCES

- BENDALL, M., 1990. Conga Oil, annual report to Tasmanian Department of Mines. June 1990.
- BURRETT, C.F., (in press). Conodont Metamorphism in the Palaeozoic of Tasmania. *Australian Journal of Earth Sciences*.
- BURRETT, C.F., LAURIE, J. & STAIT, B., 1981. Gordon Subgroup (Ordovician) carbonates at Precipitous Bluff and Point Cecil, southern Tasmania, Australia. *Papers and Proceedings of the Royal Society of Tasmania* 115: 93-99.
- BURRETT, C.F. & MARTIN, E., 1989 (Eds). *GEOLOGY AND MINERAL RESOURCES OF TASMANIA*. Geological Society of Australia Special Publication 15: 574 pp.
- BURRETT, C.F., STAIT, B. & LAURIE, J., 1983. Trilobites and microfossils from the Middle Ordovician of Surprise Bay, Tasmania, Australia. *Memoirs of the Association of Australasian Palaeontologists* 1: 177-193.
- BURRETT, C.F., STAIT, B., SHARPLES, C. & LAURIE, J., 1984. Middle to Upper Ordovician shallow platform to deep basin transect, southern Tasmania, Australia. In Bruton, D.L. (Ed.) *ASPECTS OF THE ORDOVICIAN SYSTEM*. Universitetsforlaget, Oslo: 149-157.
- DENWER, K., 1986. Geology and Geochemistry of the Tasmanite Oil Shale. Unpublished thesis, University of Tasmania: 84 pp.
- HOFFMANN, C.F., FOSTER, C.B., POWELL, T.G. & SUMMONS, R.E., 1987. Hydrocarbon biomarkers from Ordovician sediments and the fossil alga *Gloecapsomorpha prisca* Zalesky 1917. *Geochimica et Cosmochimica Acta* 51: 2681-2697.
- LEAMAN, D.E., 1978. Use of the reflection method in Tasmania. Part 1. Equipment, techniques and problems. *Tasmanian Department of Mines, Geophysics Special Report 7*.
- LEAMAN, D.E., 1986. Interpretation and evaluation report. 1981 West Tasmania aeromagnetic survey. *Mt Read Volcanics Project Report*. Tasmanian Department of Mines.
- LEAMAN, D.E., 1987. Review. Structural implications of geophysical data. Sorell Peninsula, western Tasmania. *Mt Read Volcanics Project Report*. Tasmanian Department of Mines, Hobart.
- LEAMAN, D.E., 1988. The Gravity field. In Burrett, C.F. and Martin, E.L. (Eds), *GEOLOGY AND MINERAL RESOURCES OF TASMANIA*. Geological Society of Australia Special Publication 15: 451-455.

M.R. Bendall, J.K. Volkman, D.E. Leaman and C.F. Burrett

- LEAMAN, D.E., 1990. Inferences concerning the distribution and composition of pre-Carboniferous rocks in southeast Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 124(1): 1-12.
- LEAMAN, D.E. & RICHARDSON, R.G., 1981. Gravity survey of the east coast coalfields. *Geological Survey of Tasmania Bulletin* 60.
- LEAMAN, D.E. & RICHARDSON, R.G., 1989. The granites of west and northwest Tasmania—a geophysical interpretation. *Geological Survey of Tasmania, Bulletin* 66.
- LEAMAN, D.E. & RICHARDSON, R.G., 1990. Tasmanian crustal features. 10th Australian Geological Convention, Hobart, February 1990. *Geological Society of Australia Abstracts* 25: 100-101.
- LEAMAN, D.E., SYMONDS, P.A. & SHIRLEY, J.E., 1973. Gravity survey of the Tamar region, Northern Tasmania. *Geological Survey of Tasmania Paper* 1.
- MACKENZIE, A.S., 1984. Applications of biological markers in petroleum geochemistry. In Brooks, J. & Welte, D. (Eds). *ADVANCES IN PETROLEUM GEOCHEMISTRY*. Academic Press, New York: 115-214.
- McKIRDY, D.M., COX, R.E., VOLKMAN, J.K. & HOWELL, V.J., 1986. Botryococcane in a new class of Australian non-marine crude oils. *Nature* 320: 57-59.
- RICHARDSON, R.G. & LEAMAN, D.E., 1981. Fingal Tier seismic reflection traverses 1 and 2. Tasmanian Department of Mines unpublished report 1981/6.
- SIMONEIT, B.R.T., GRIMALT, J.O., WANG, T.G., COX, R.E., HATCHER, P.G. & NISSENBAUM, A., 1986. Cyclic terpenoids of contemporary resinous plant detritus and of fossil woods, ambers and coals. *Organic Geochemistry* 10: 877-889.
- TWELVETREES, W.H., 1917. The search for petroleum in Tasmania. *Tasmanian Department of Mines Circular* No. 2, 1-18.
- VOLKMAN, J.K., ALEXANDER, R., KAGI, R.I. & WOODHOUSE, G.W., 1983. Demethylated hopanes in crude oils and their applications in petroleum geochemistry. *Geochimica et Cosmochimica Acta* 47: 785-794.
- VOLKMAN, J.K., EVERITT, D.A. & ALLEN, D.I., 1986. Some analyses of lipid classes in marine organisms, sediments and seawater using thin-layer chromatography-flame ionisation detection. *Journal of Chromatography* 356: 147-162.
- VOLKMAN, J.K., ROGERS, G.I., BLACKMAN, A.J. & NEILL, G.P., 1988. Biogenic and petroleum hydrocarbons in sediments from the D'Entrecasteaux Channel near Hobart, Tasmania. In *AMSA SILVER JUBILEE COMMEMORATIVE VOLUME*. Wavelength Press, Chippendale, NSW: 82-86.
- WILLIAMS, E., 1979. *Tasman Fold Belt System in Tasmania*. Explanatory notes for 1:500,000 structural map of Pre-Carboniferous rocks of Tasmania. Tasmanian Department of Mines.

0019

369020

APPENDIX 2:

**EVIDENCE FOR A NEW MARINE OIL IN SOUTHERN AUSTRALIA
FROM BIOMARKER ANALYSES OF TASMANIAN OIL SEEP BITUMENS**

J. K. VOLKMAN¹, T. O'LEARY¹, M. R. BENDALL²
R. E. SUMMONS³ and D. G. HOLDSWORTH¹

¹CSIRO Division of Oceanography, GPO Box 1538, Hobart, Tasmania 7001

²Conga Oil Pty Ltd, 84 Wells Parade, Blackmans Bay, Tasmania 7052

³Bureau of Mineral Resources, GPO Box 378, Canberra, ACT 2601.

No oil was recovered from the first wild cat well in Tasmania which was drilled on Bruny Island south of Hobart, in 1915. However another well drilled in 1929 reportedly produced small quantities of oil and gas from shallow depth. In the early 1920s, over 30 wells were drilled into Tertiary on-shore deposits to find the source of the many tars which had been reported along the west coast of Tasmania, but these too did not lead to commercial discoveries. On-shore exploration activity continued sporadically until 1984 when Conga Oil reinvestigated the original Bruny Island oil show. Biomarker analyses of exposed sediments near the drilling site confirmed the presence of petroleum-derived hydrocarbons whose sterane fingerprint closely matched those of Ordovician carbonates from Ida Bay and Queenstown, although hopane distributions were not identical.

A search of archival records by M. R. Bendall revealed over 260 seepage sites during the last 100 years. From information in a 1917 paper by the government geologist W. H. Twelvetrees, we learned that the Queen Victoria Museum in Launceston contained specimens of the original oil seep tars collected from the west coast of Tasmania, Flinders Island and King Island. Biomarker analyses confirmed that all of these tars were derived from a mature oil from the same source. Maturity parameters were almost identical, and source parameters confirmed that the tars were not related to oils presently recovered from the Bass and Gippsland Basins. The high proportions of C₂₇ and C₂₈ steranes, and presence of C₃₀ steranes including dinosterane, were consistent with a marine source rock. The hopanes showed a high proportion of C₂₉ and C₃₀ 17 α (H),21 β (H)-hopanes with very minor amounts of the corresponding moretanes which is typical of mature crudes. The absence of 2-methylhopanes and low abundance of tricyclic alkanes respectively ruled out carbonates or the Tasmanite Oil Shale as source rocks. Although much of the geological and geochemical data suggest that the source rocks might be marine shales deposited in the late Ordovician, the presence of dinosterane in such old sediments seems anomalous.

Tars with the same biomarker composition have also been found at Preolenna in north-west Tasmania, at Cape Jaffa in South Australia and on the south coast of Western Australia testifying to the widespread occurrence of this oil. Gravity, seismic and magnetic studies imply that previous views of the geology of Tasmania require major revision. In particular, we suggest that there has been widespread tectonic disruption of lower Palaeozoic sequences and there is evidence for a westward trending thrust stack. These new findings have major ramifications for future oil and mineral exploration in Tasmania and adjacent areas.

APPENDIX 3:

FIGURES REFERRED TO IN THE TEXT

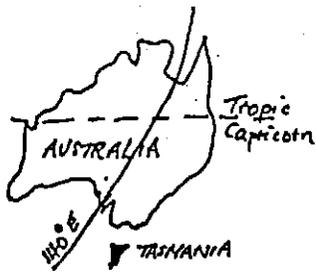
1: Location of licence area

DIAGRAMS ILLUSTRATING HISTORY OF OIL EXPLORATION IN TASMANIA AND PROGRESS MADE BY CONGA OIL as used for display, paper presentation, and company negotiation purposes.

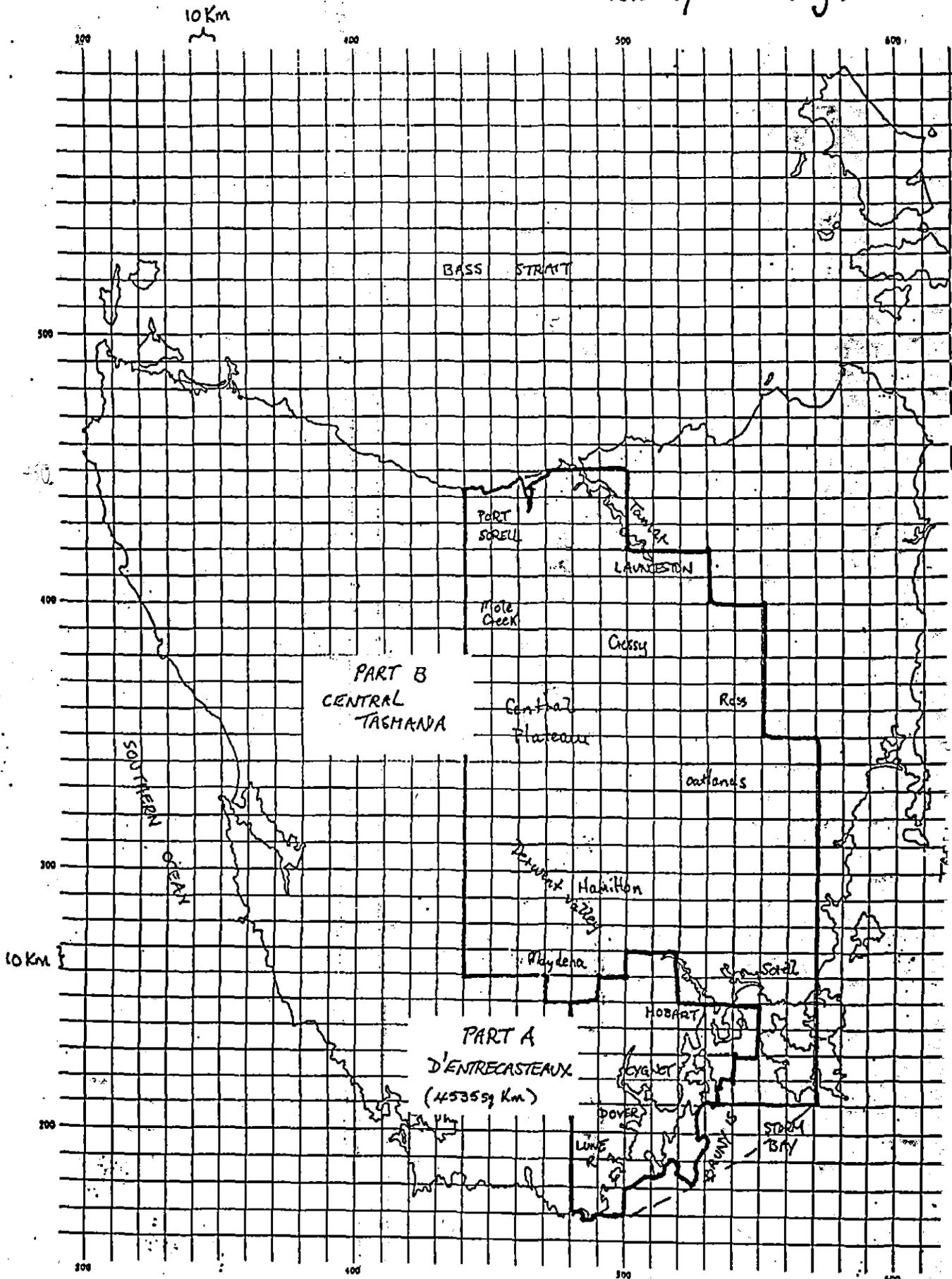
The notes below draw attention to the critical aspect of each diagram.

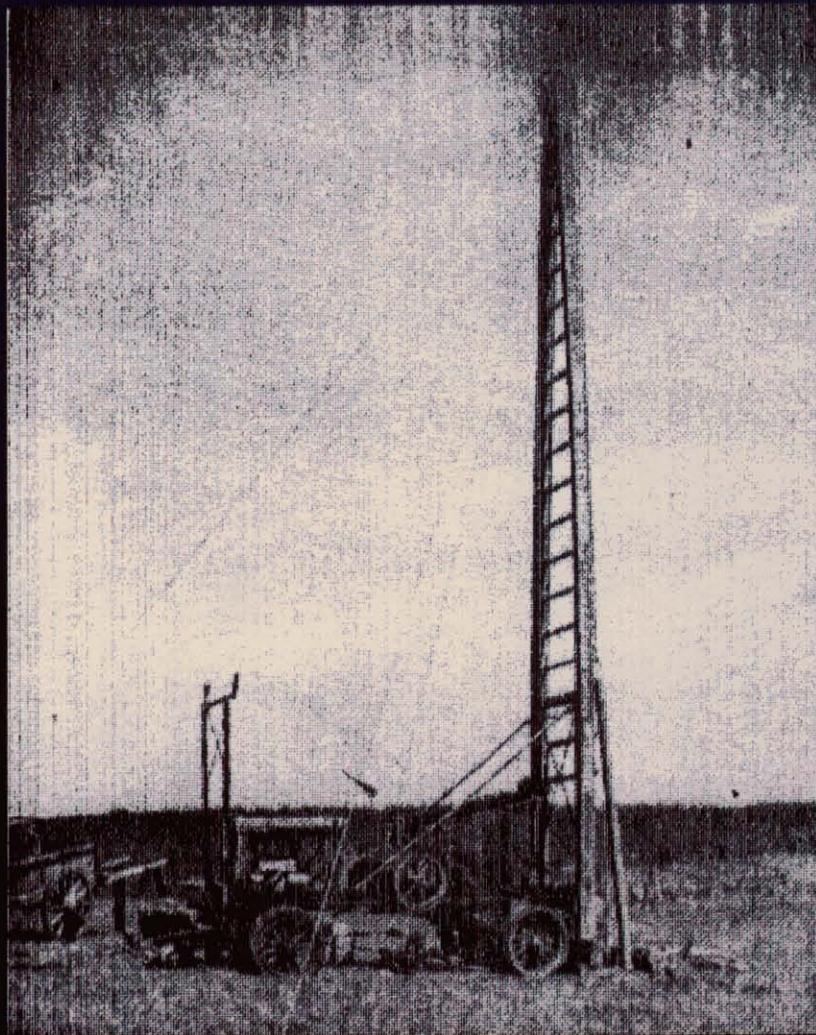
- 2: Example of previous drilling attempts in the Launceston area in 1939.
 3: Published example of tars recovered from Port Davey in 1915-a shipload was brought to Hobart.
 4: Example of previous drilling at Bruny Island (1929)
 5: Nature of alkane fingerprint in petroleum identification.
 6 to 23: Chemical analyses
 Port Davey tar: 6-12
 Queenstown lmsst tar: 7-15-17-20
 Poatina base Permian: 16-23
 Preolenna tar: 11-13-18-21
 Bridgewater tar: 8-10-14-22

 Steranes: 6-17-18-19-20-21-22-23
 Aliphatics: 12-13-14-15-16
 Methyl hopanes: 7-8-10-11
- 19, 24: Location of known seepage sites.
 25-26: Concept of reef development within the Gordon Group. Diagrams suggest variations in composition and limestone type with respect to the sea during deposition.
 27: Facies zones for the Gordon Group in southern Tasmania.
 28: Seep occurrences and conodont alteration indices. Information limited by post Carboniferous cover.
 29, 31: Bouguer anomaly (includes crust and mantle responses)
 30: Aeromagnetic compilation acquired by Conga Oil in central Tasmania.
 32: Residual Bouguer anomaly. Separation based on process known as Mantle88 which generates a model for the crust-mantle effect and removes it. Residuals valid for upper half of crust.
 33: Correlation between residual Bouguer anomaly and seepage sites.
 34: Correlation between magnetic data and seepage sites. Note correlations with quieter zones, marked trends and the region north of the Port Sorell-Bracknell thrust belt.
 35: Correlation between magnetic field and surface geology - very little, showing the role of pre- Permian rocks.
 36, 37: Seep occurrences and location of section lines.
 38, 39: Gravity models for southern Tasmania. Cretaceous synclines present as large laccolith, Cambrian volcanics as thick piles. Thin slices of other Lower Palaeozoic rocks.
 40: Current interpretation of materials directly beneath the Permian unconformity.
 41, 42, 43: South west Tasmania section, as conceived by Conga, as previously conceived.
 Thrusting accounts for seepages through Precambrian rocks.
 44, 45: Structural model for northwest Tasmania. Seepages from concealed Ordovician rocks.
 46, 47: Structural model for northern Tasmania.
 48, 49: Structural model and indicated relationships for central Tasmania. Known seep correlations shown.
 50, 51: Thrust model diagrams. 51 suggests true position of Tasmania with much basement-involvement.
 52, 53, 54: Only seismic section yet available in fully assembled and corrected mode but yet to be migrated.
 54 suggests some of the large faults, difference between the Bruny and Tasman regions, and a thrust position (yellow line).
 55, 56: Conceptual diagram suggesting the Ordovician position of Tasmania and relationships to other Australian basins.
 57: Map summarising knowledge of Tasmanian Palaeozoic geology prior to Conga Oil.
 58, 59: Interpretation of Tor granite defining major fracture system which can be correlated with many seeps
 60: Location of dolerite feeders in southern Tasmania.
 61: Polycyclic alkane signature.
 62: Conclusions.



TASMANIA
EL 1/88 Conga Oil





TASMANIAN OIL BORE No. 1

NOW DOWN 100 FT.

One of seven bores which is being drilled under the personal supervision of Mr. Max Steinbuchel, the American Oil Expert, at Launceston close to Tamar River by Producers' Oilwell Supplies Ltd.

(The Mercury newspaper 31st October 1939.)

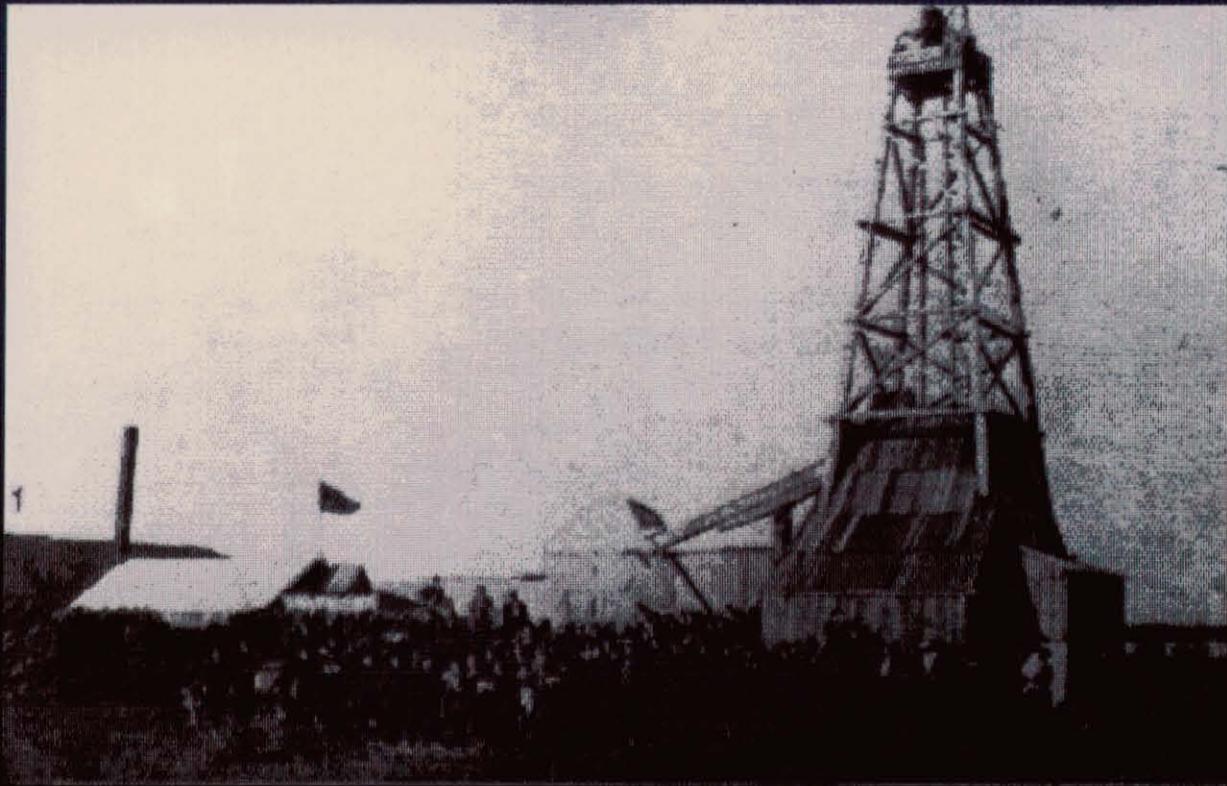
AP9118G-78

0023

369024



**Specimens of bitumen found at
Deep Creek, Port Davey, by the
Davey River Oil and Mineral
Exploration Co's prospecting party.**



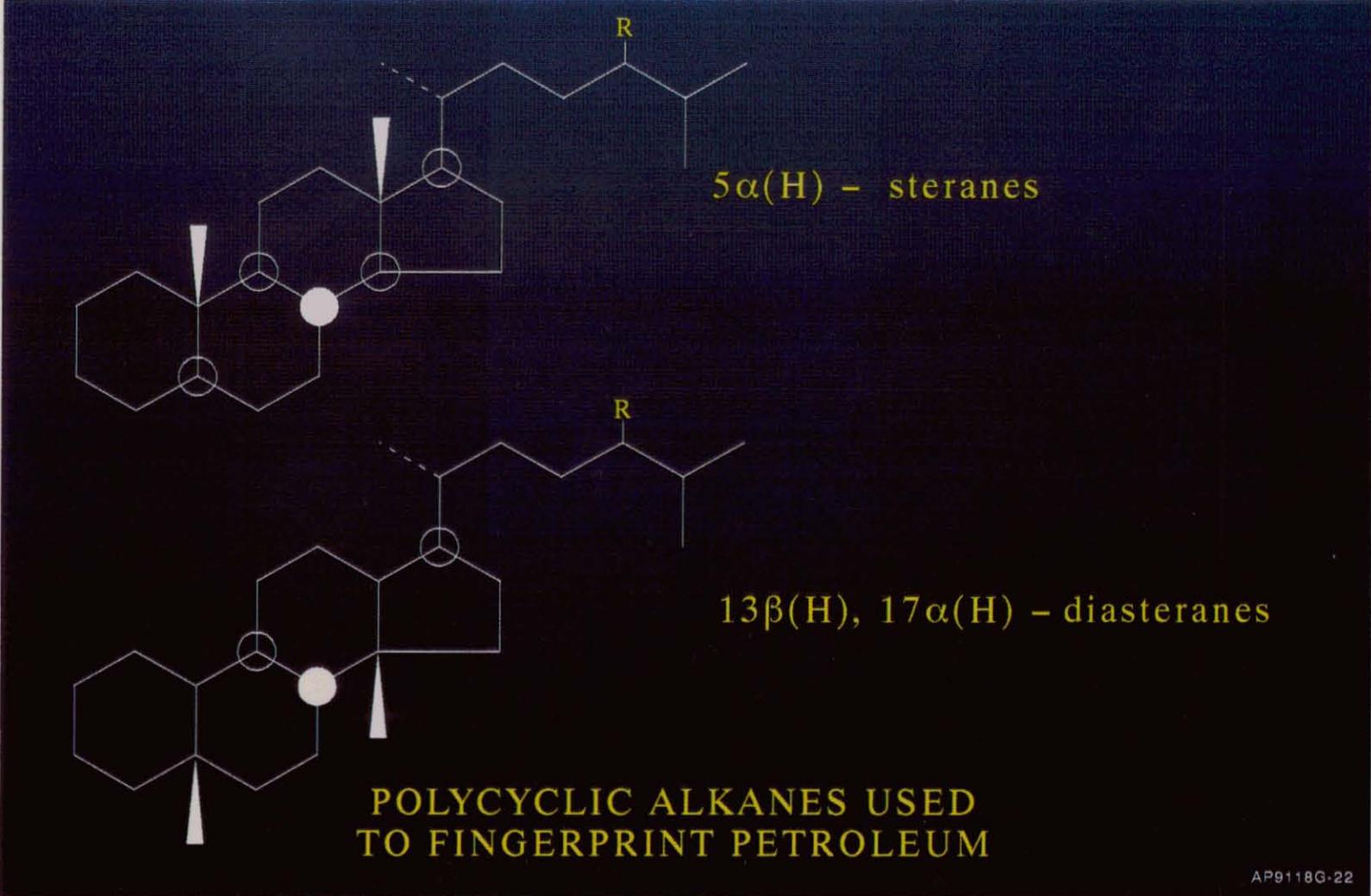
**Visitors from Hobart who
recently inspected the works at Bruny Island,
where boring operations are being conducted.**

0025

369026

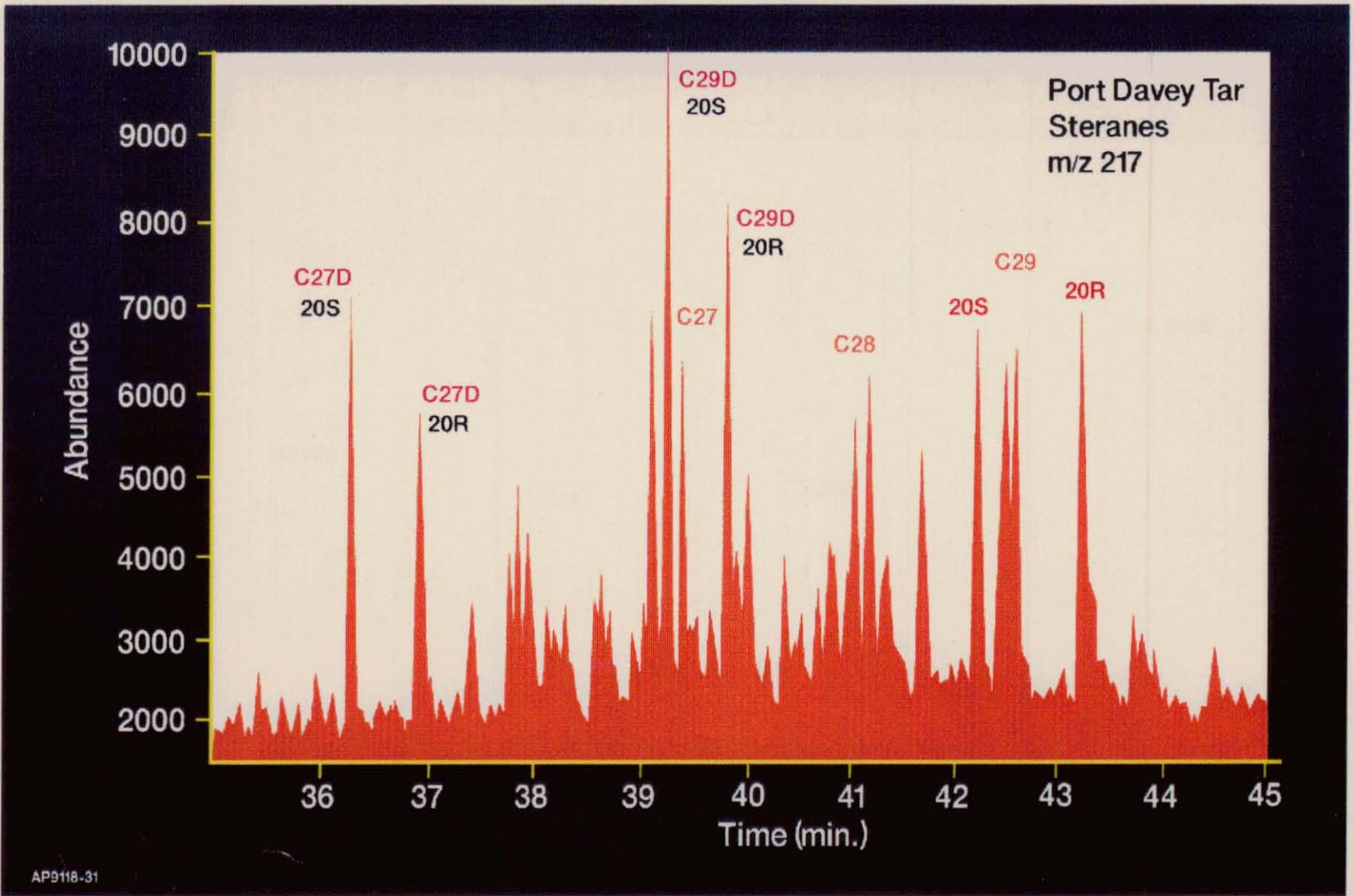
2

0026



369027

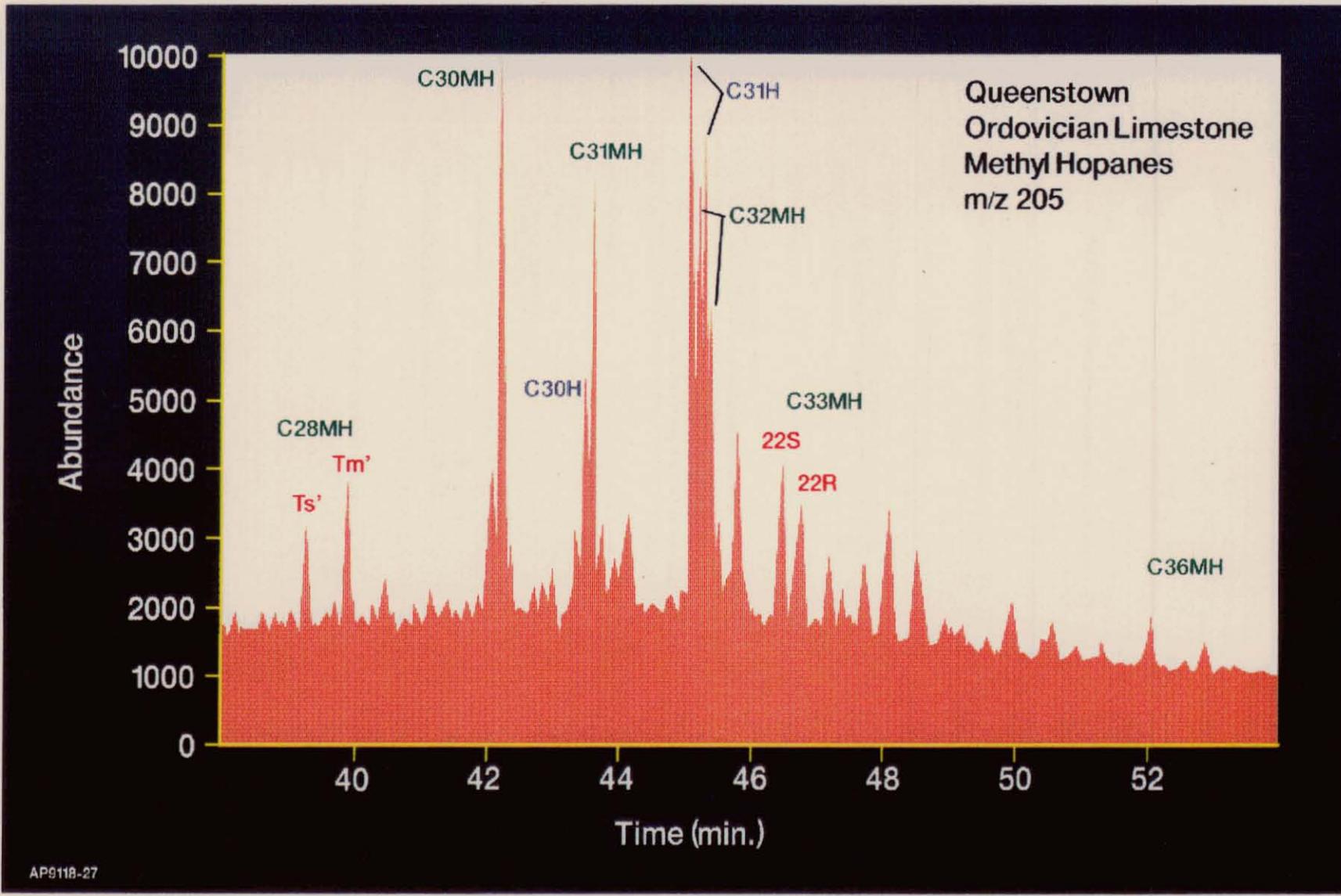
0027



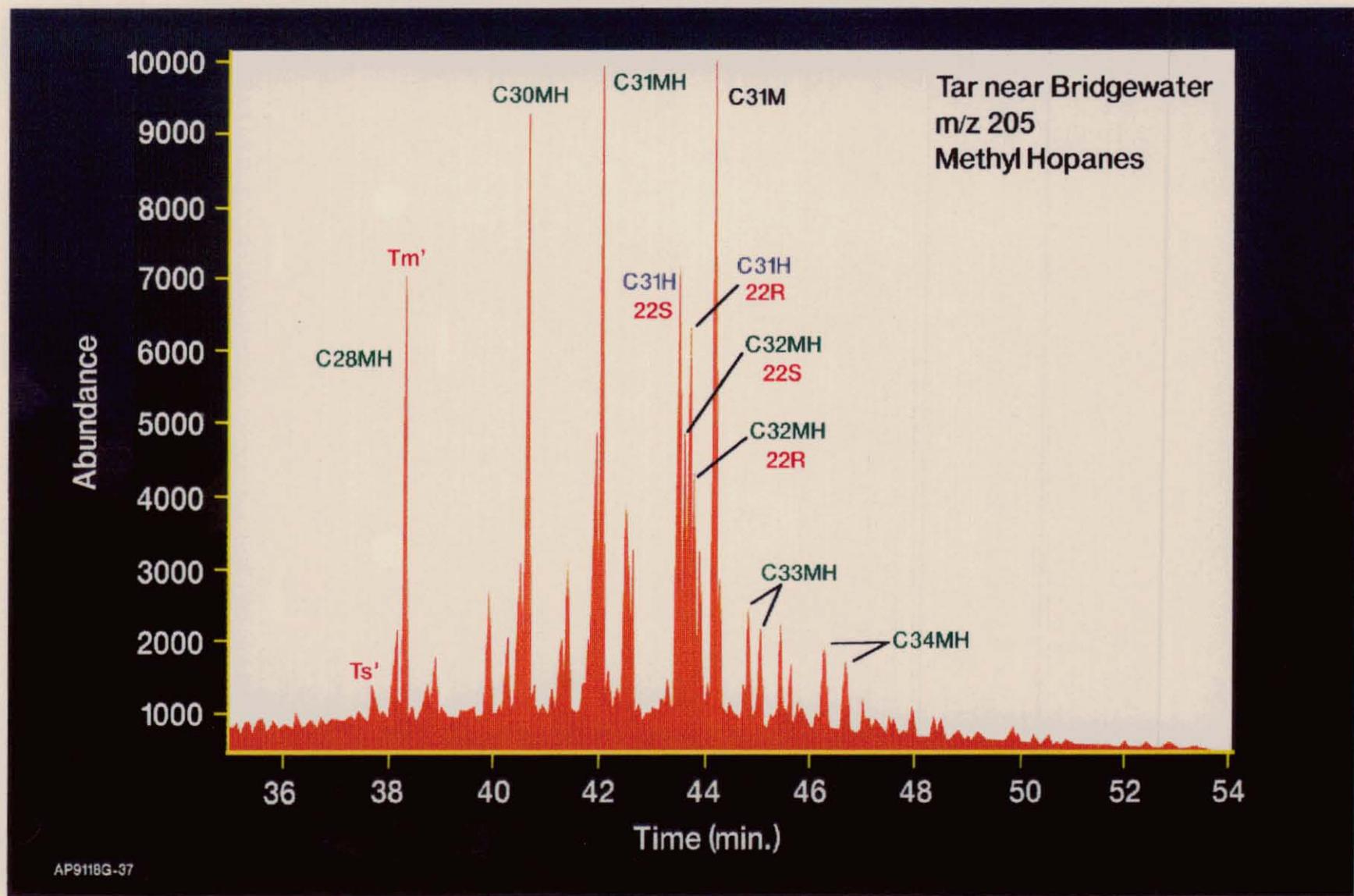
AP9118-31

369028

9

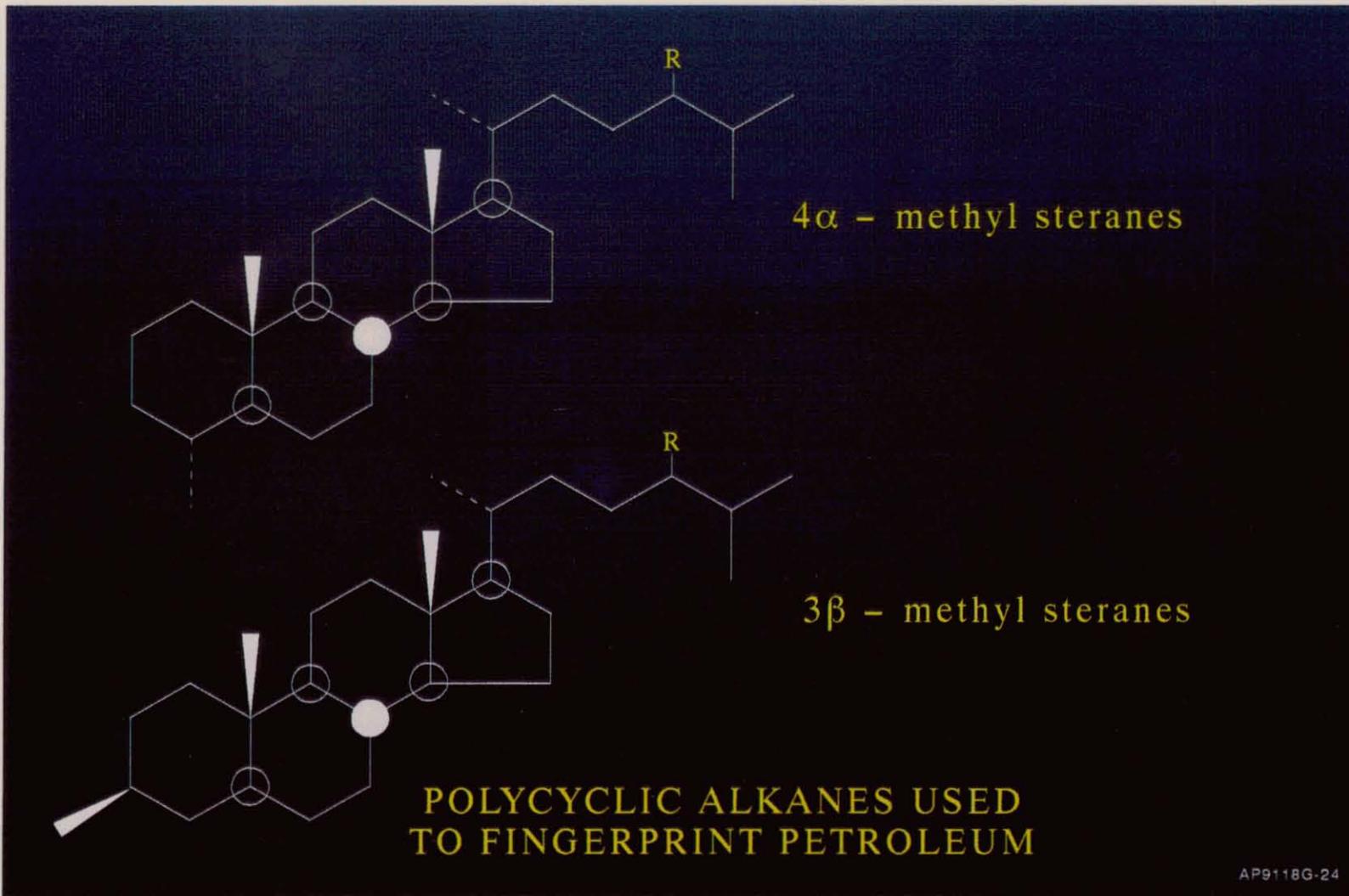


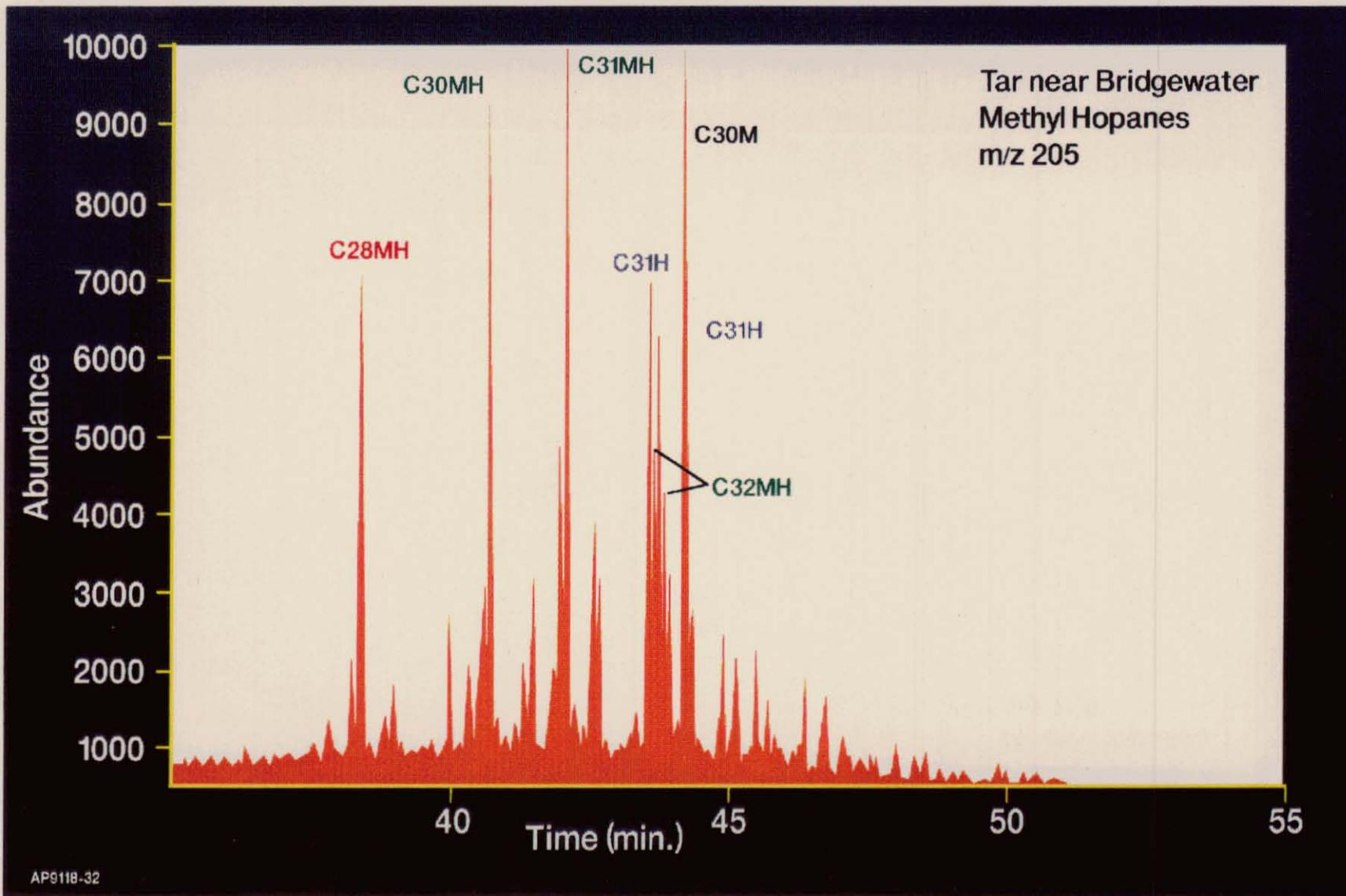
AP9118-27



AP9118G-37

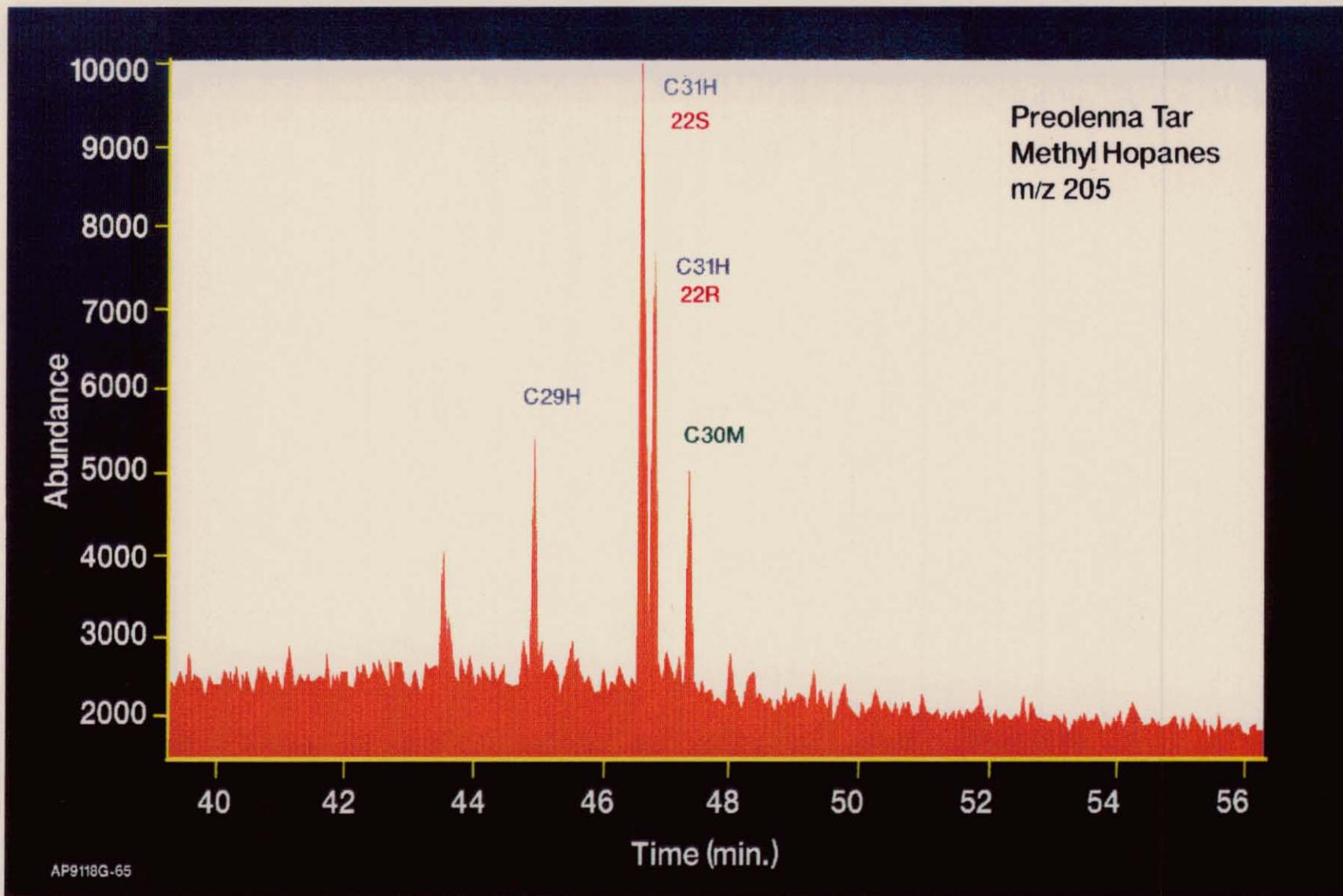
8



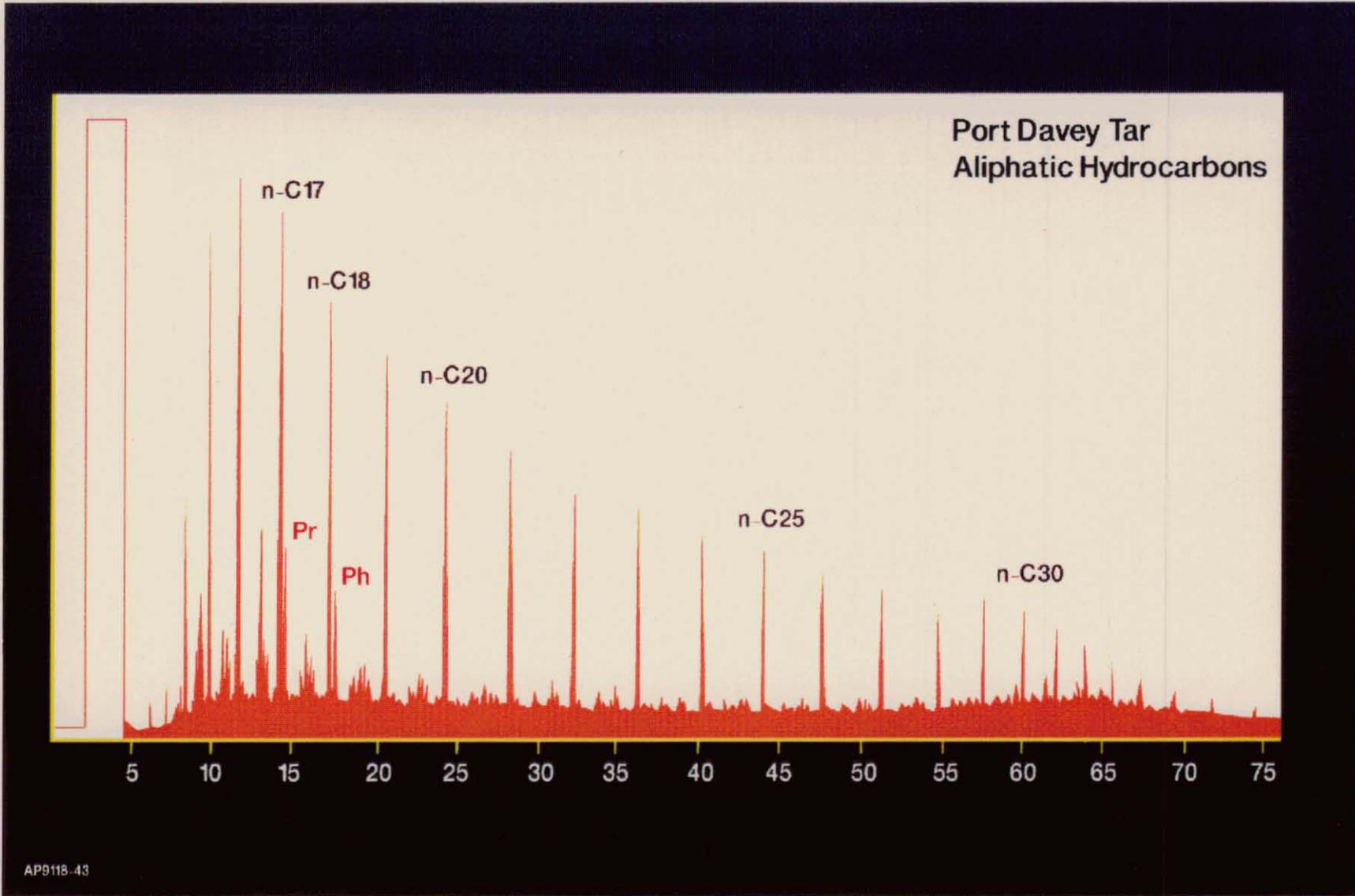


0032

369033

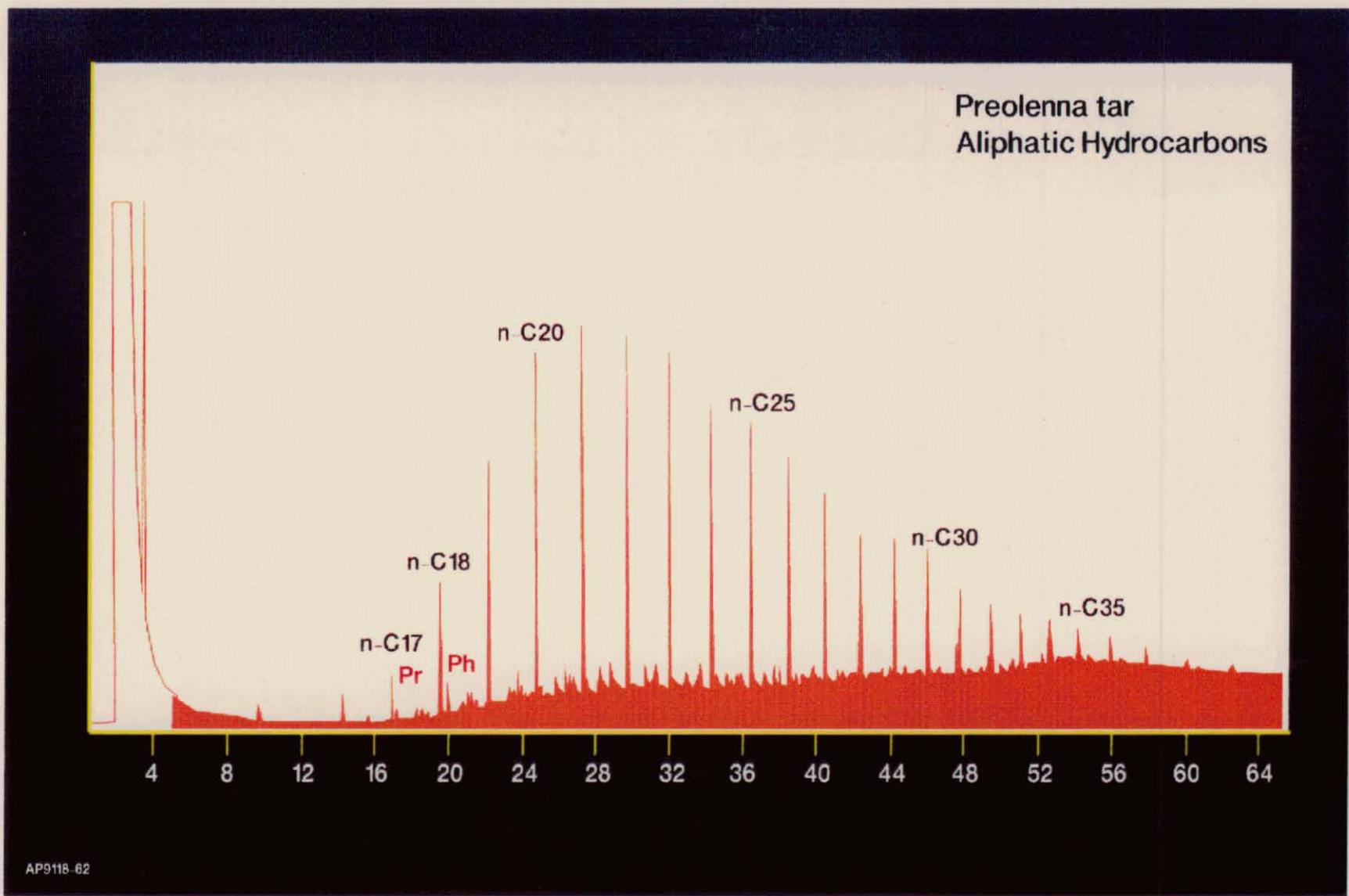


0033

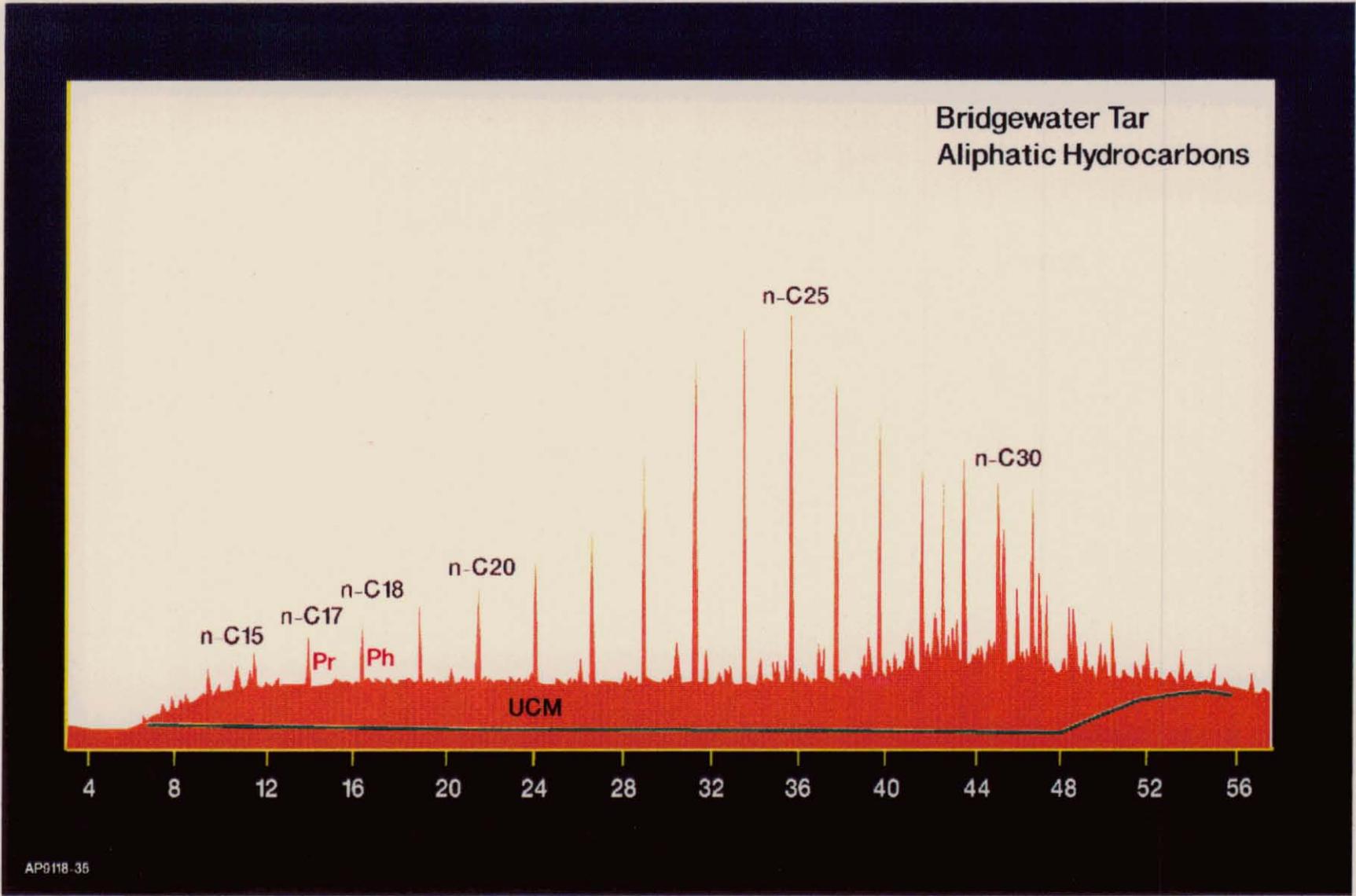


369034

12



0035

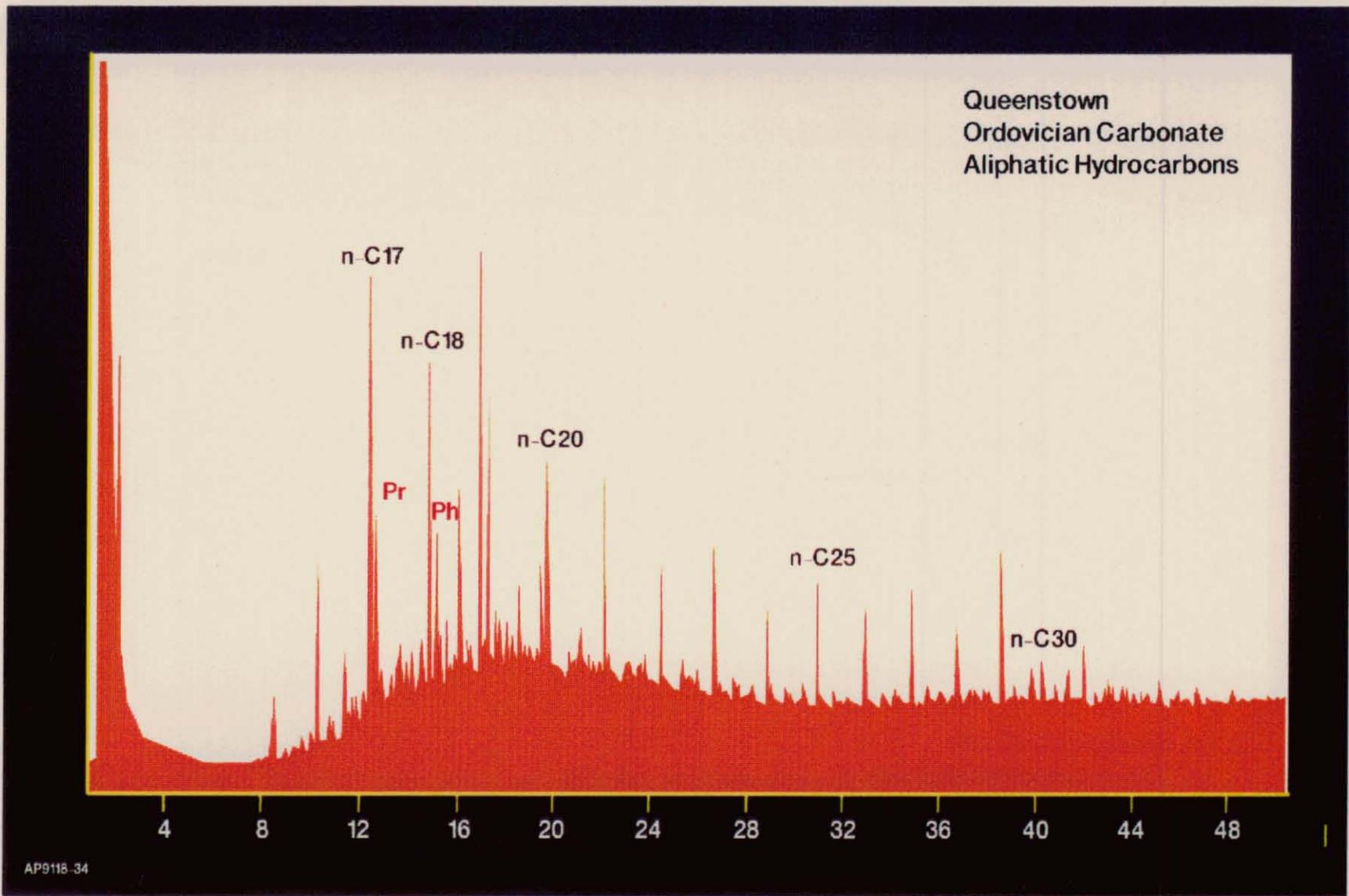


369036

11

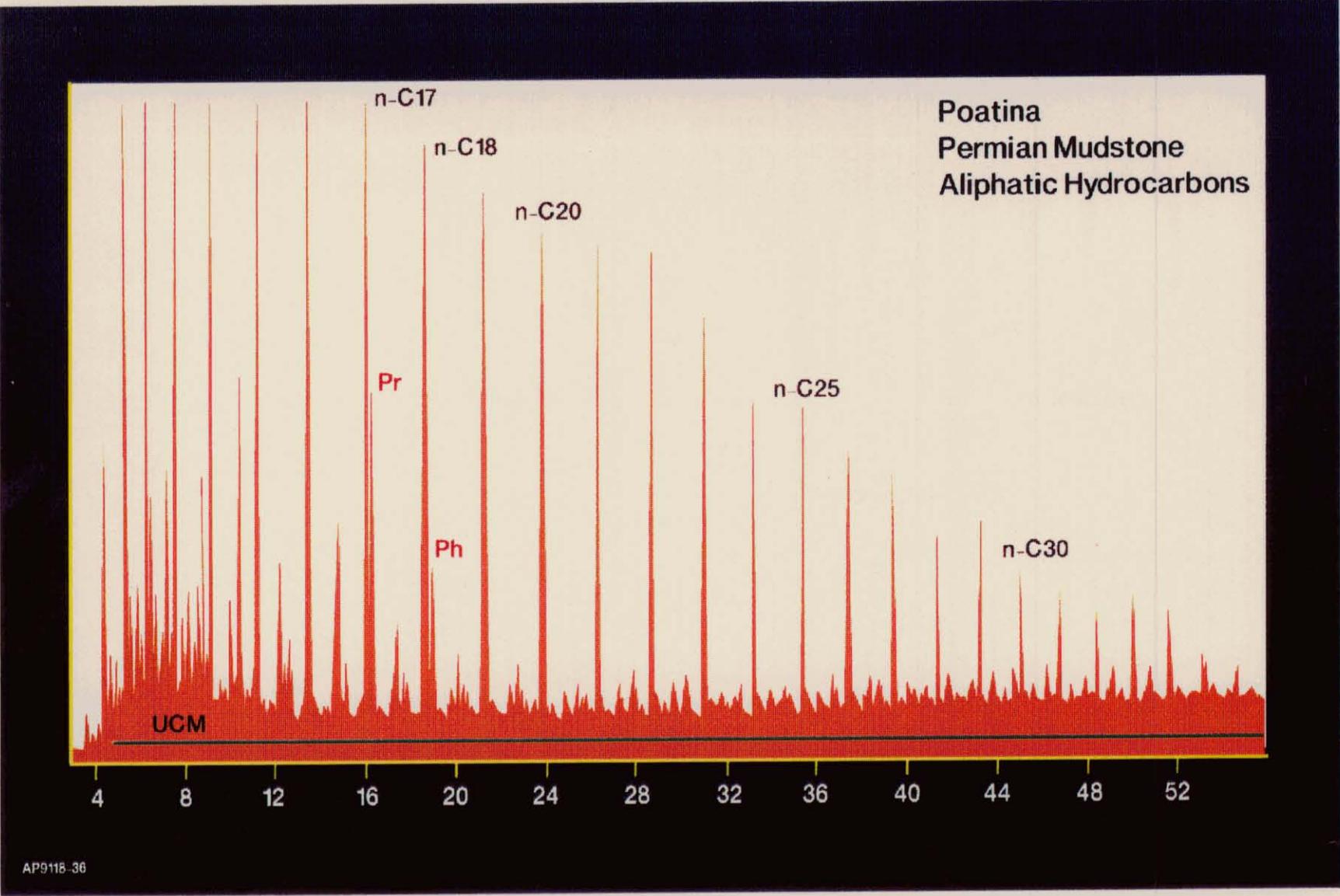
15

0036



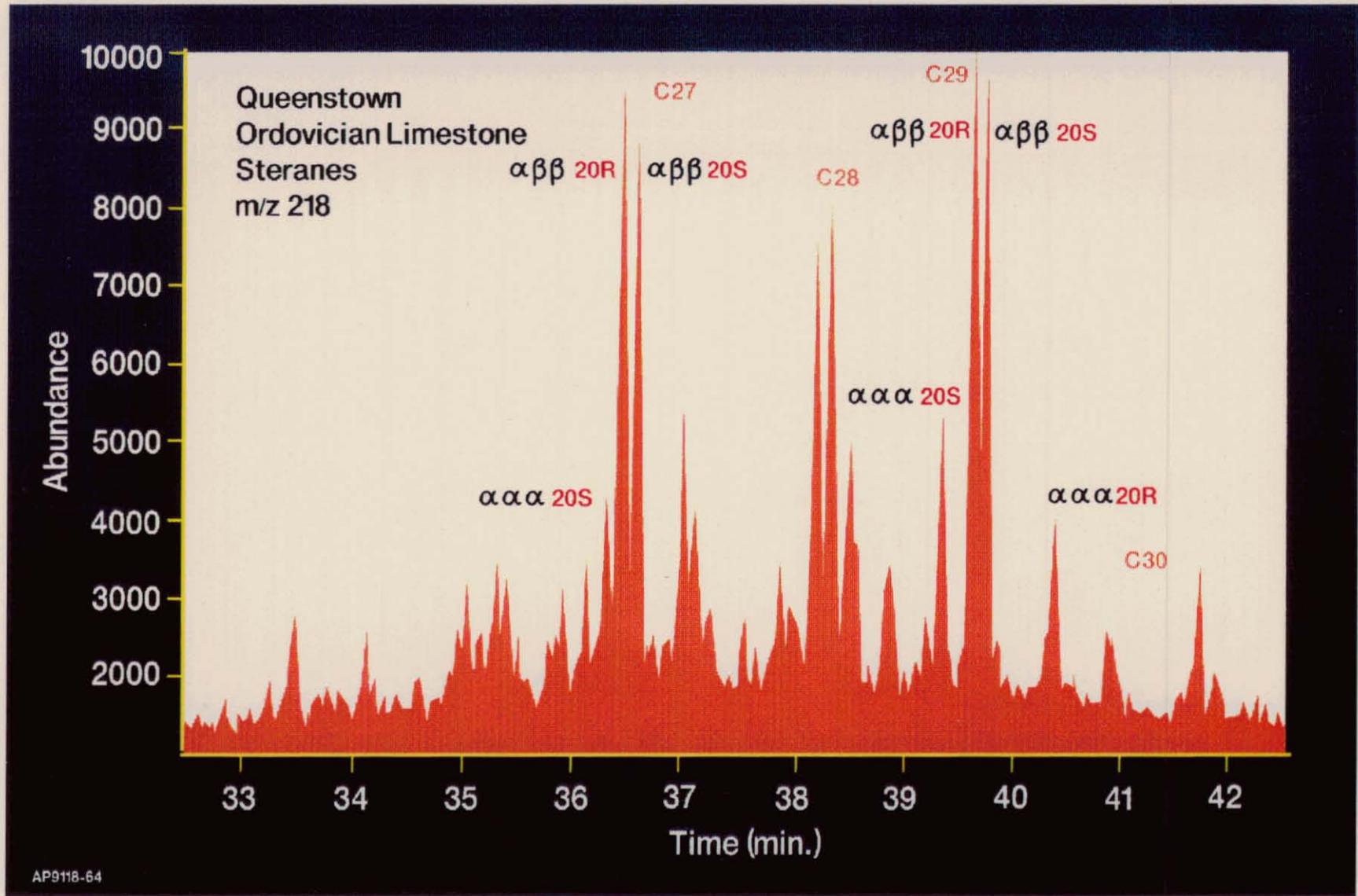
369037

0037

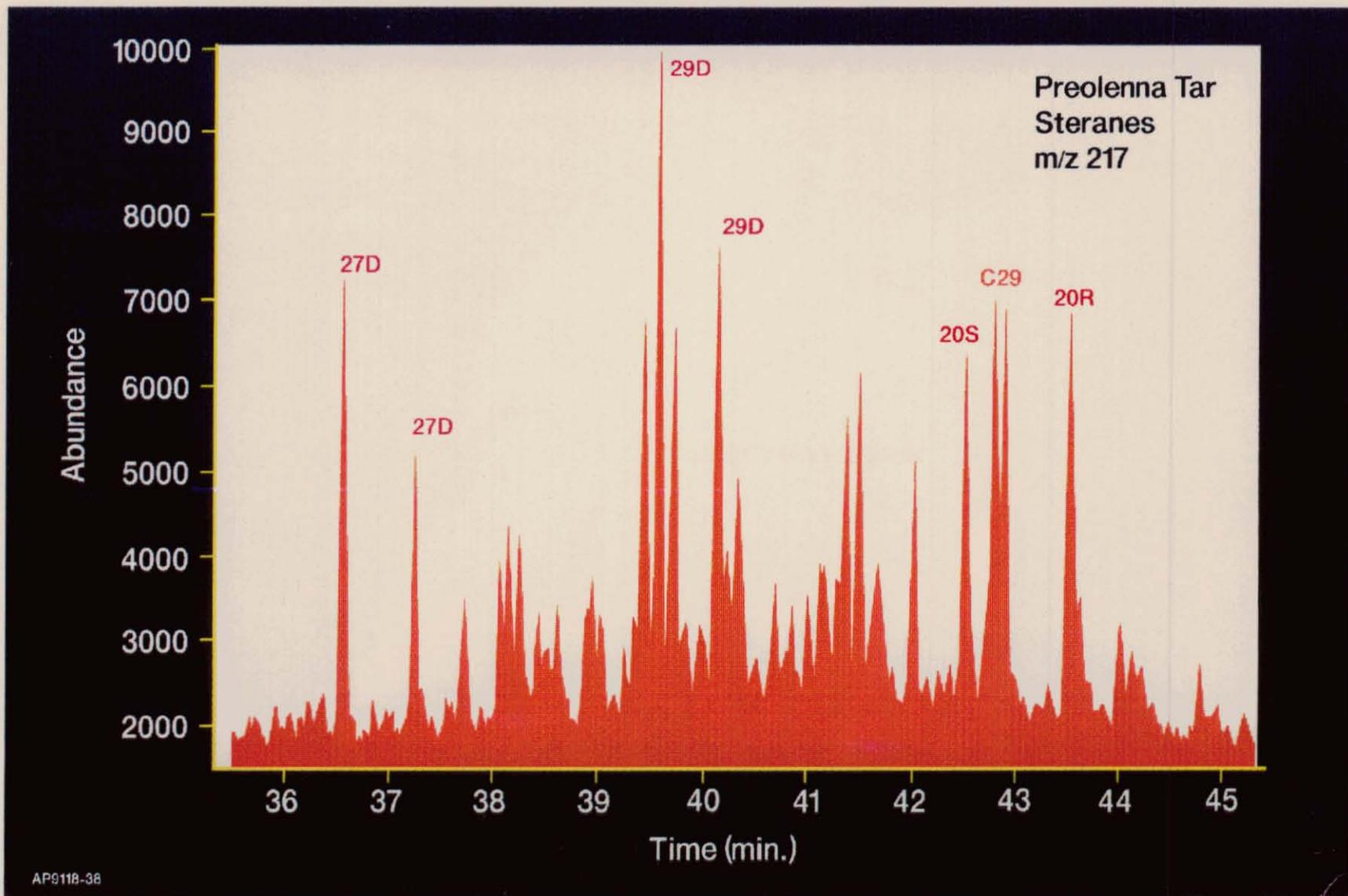


369038

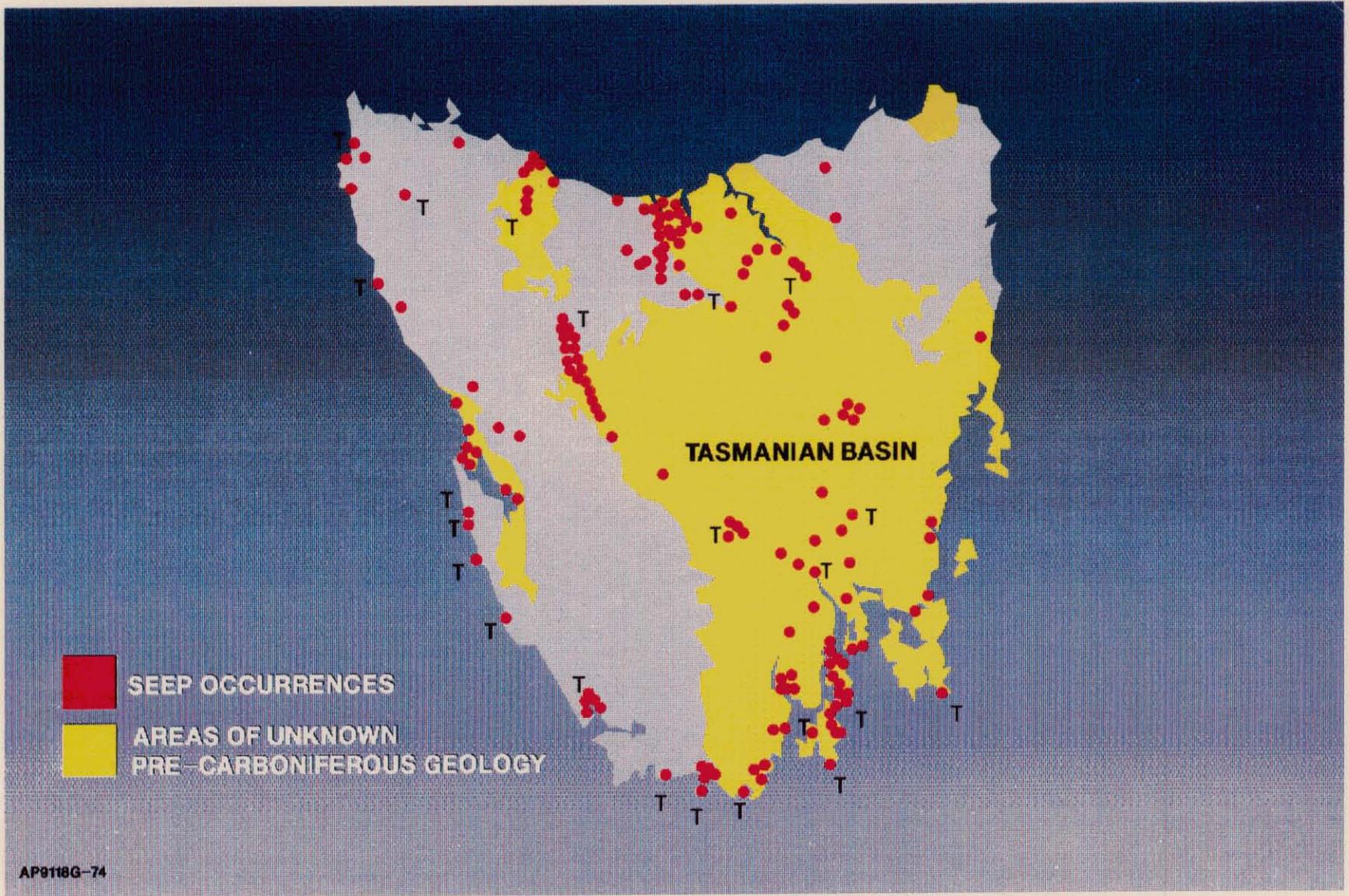
91



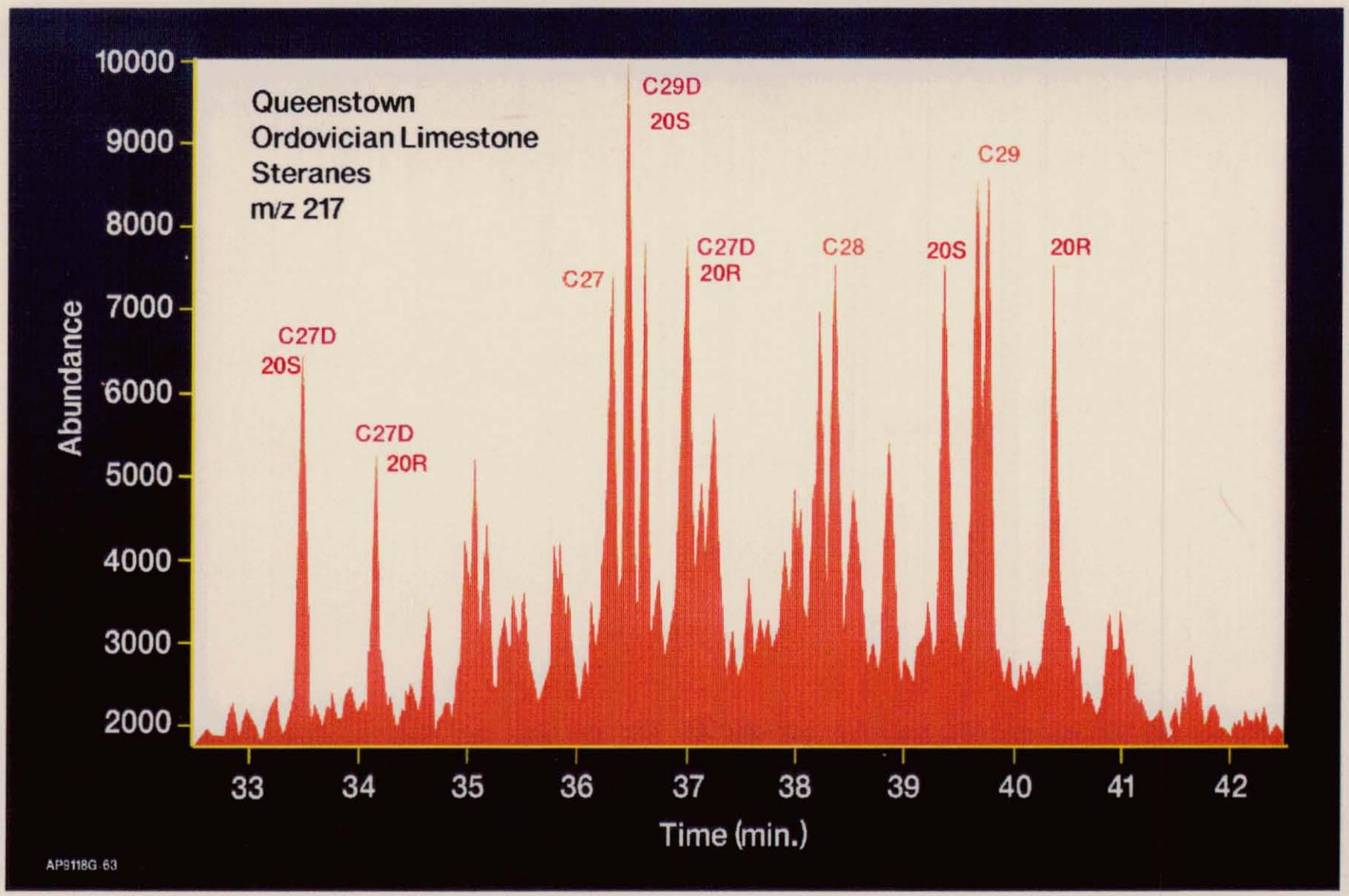
0039



369040



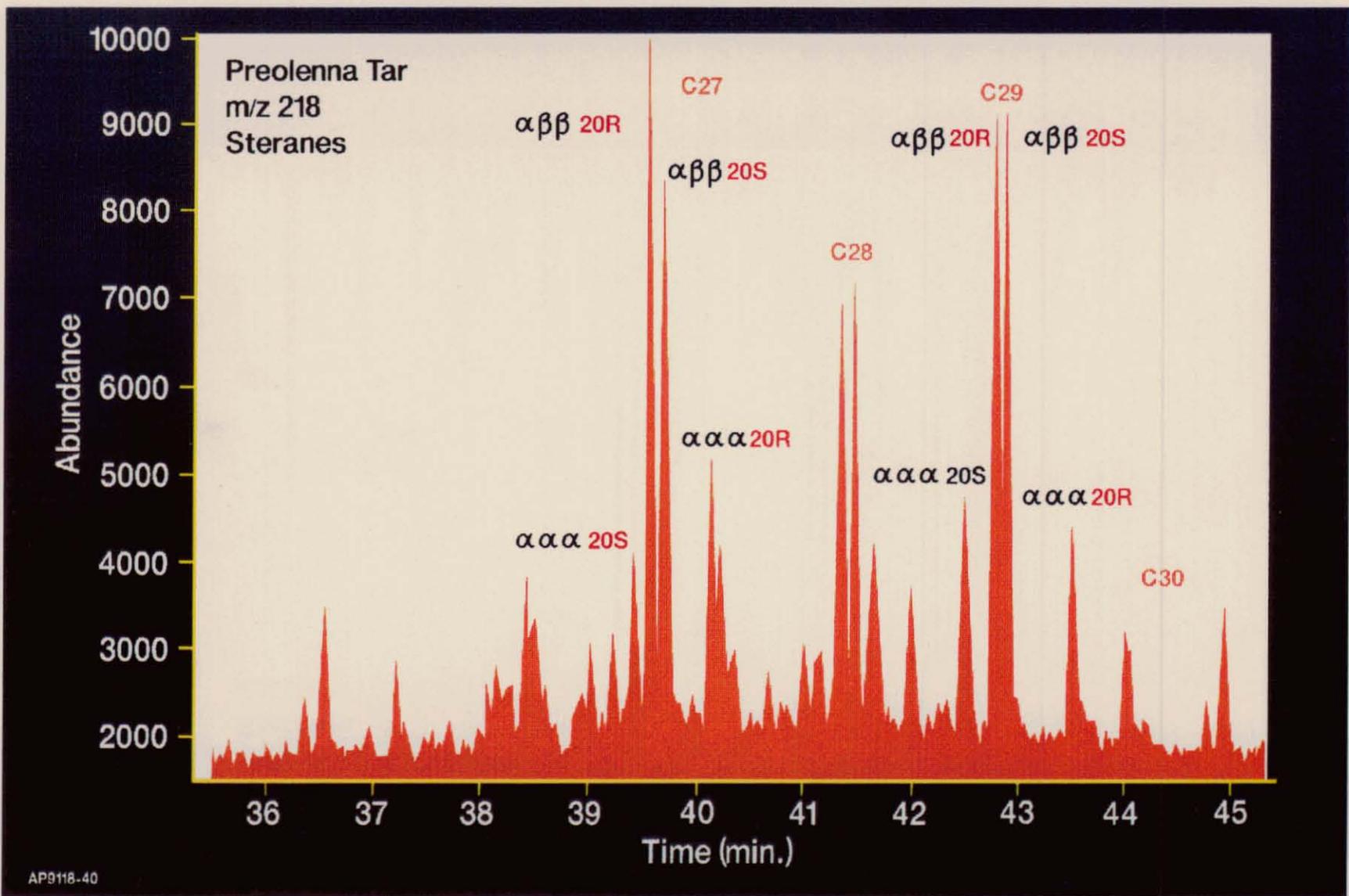
0041

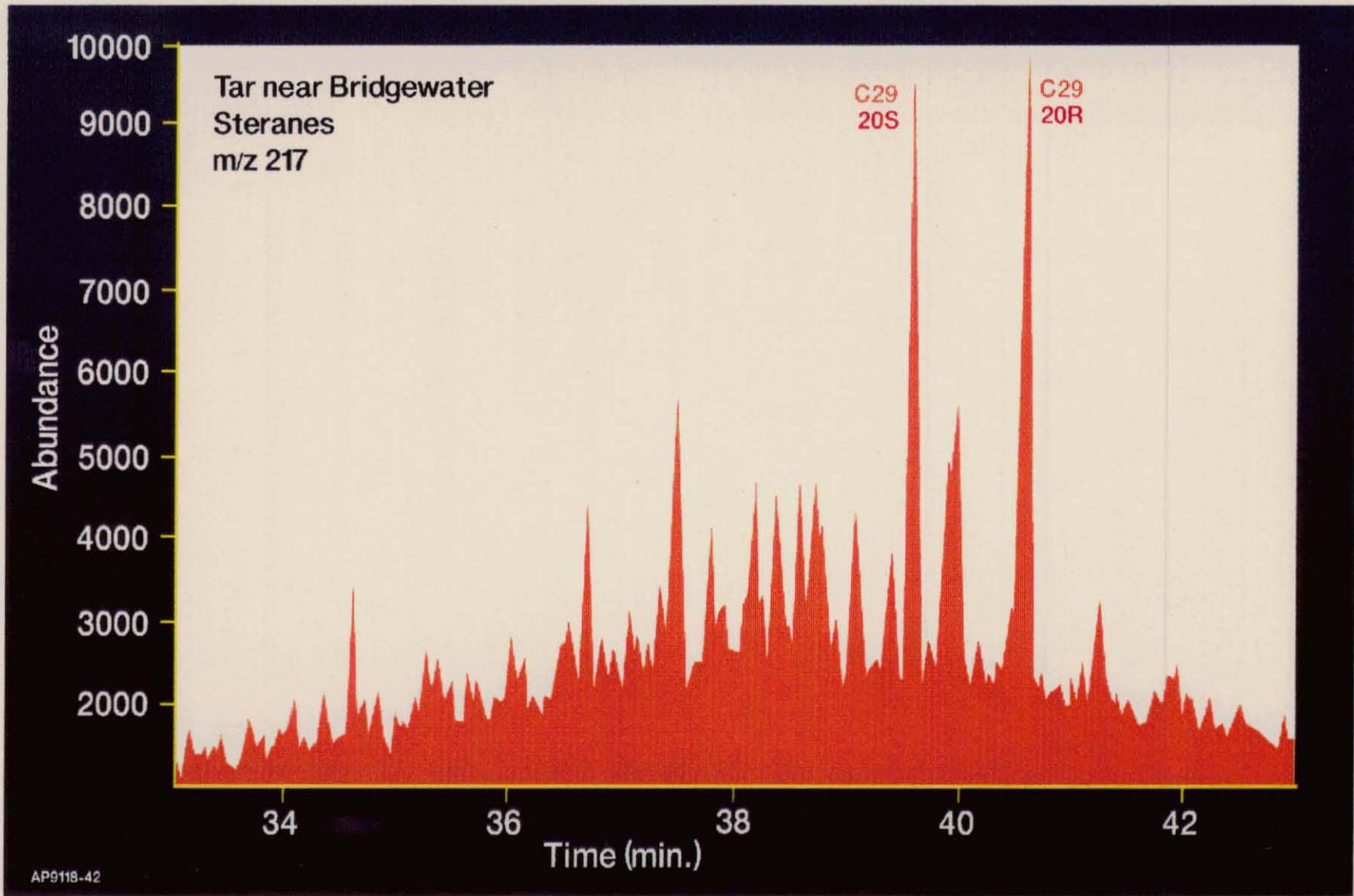


AP9118G 63

369042

20

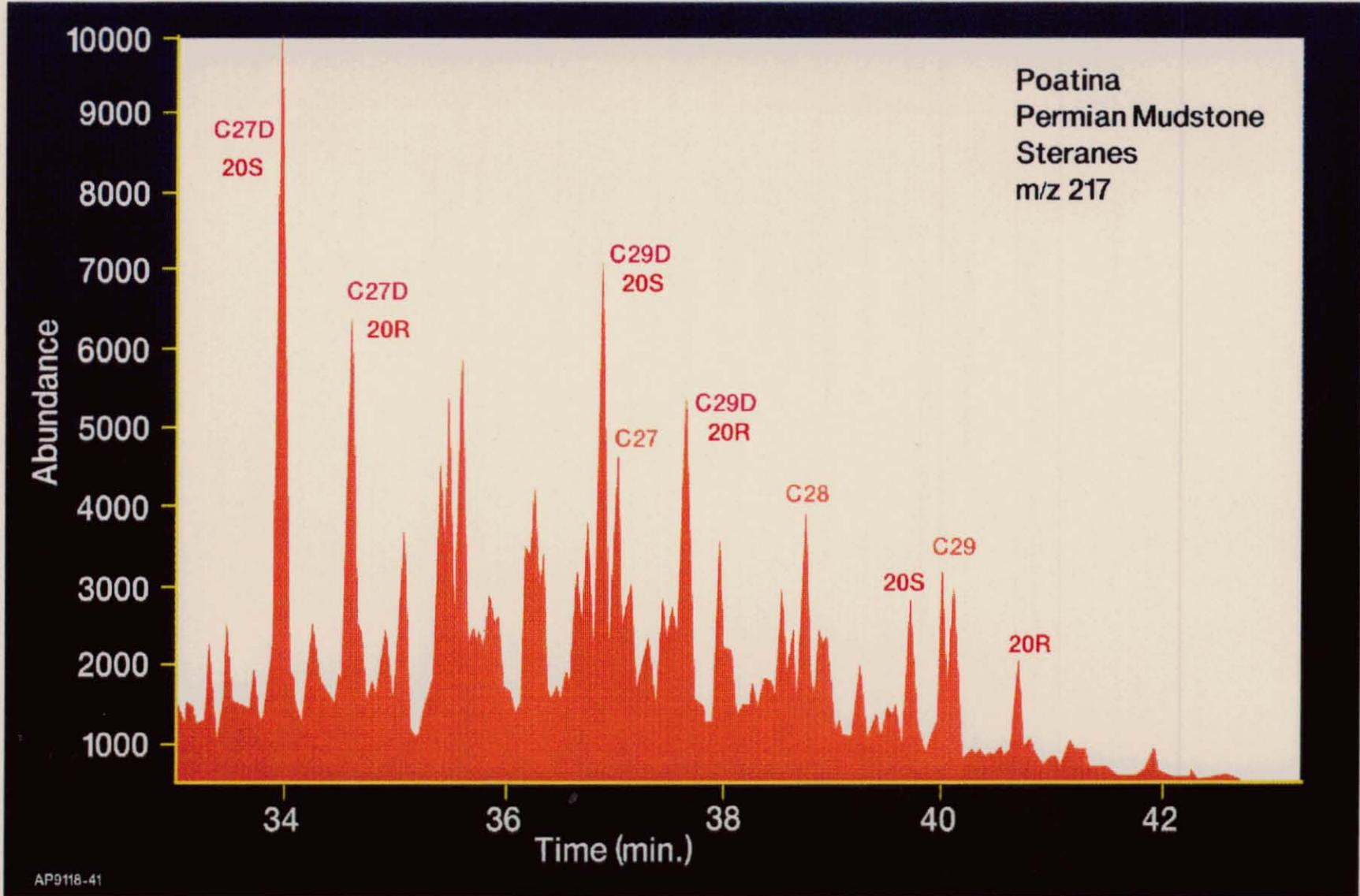


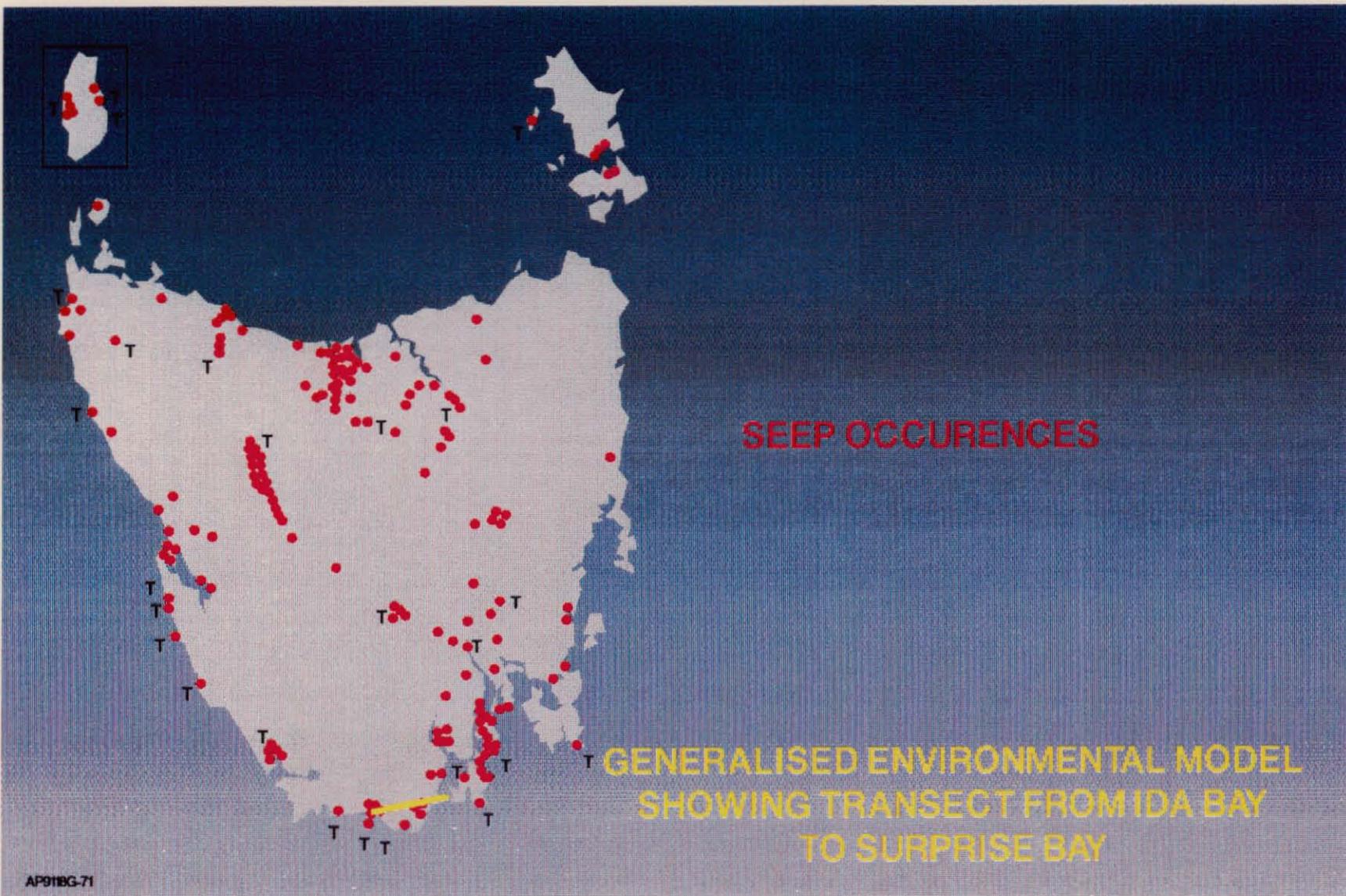


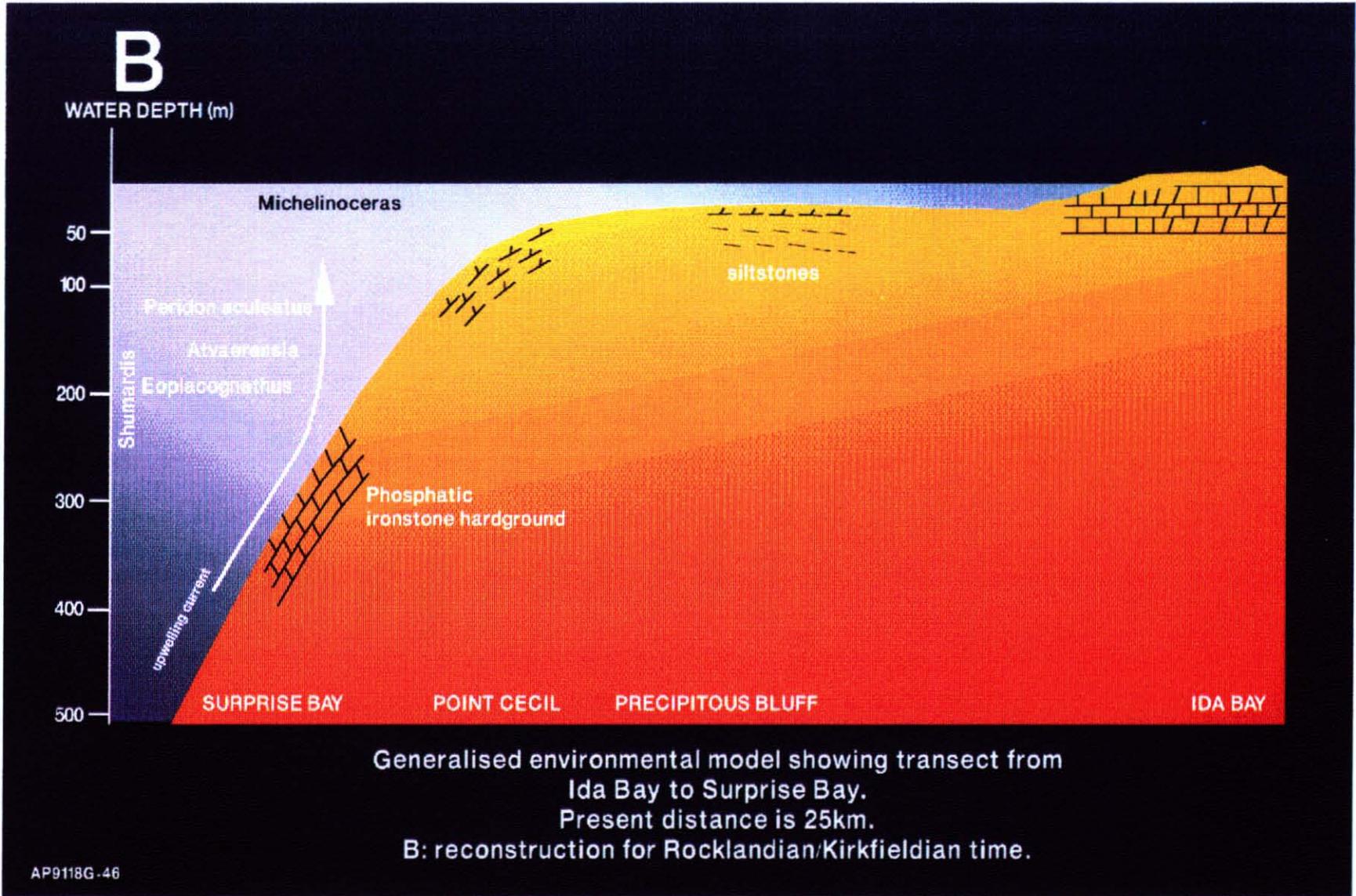
0043

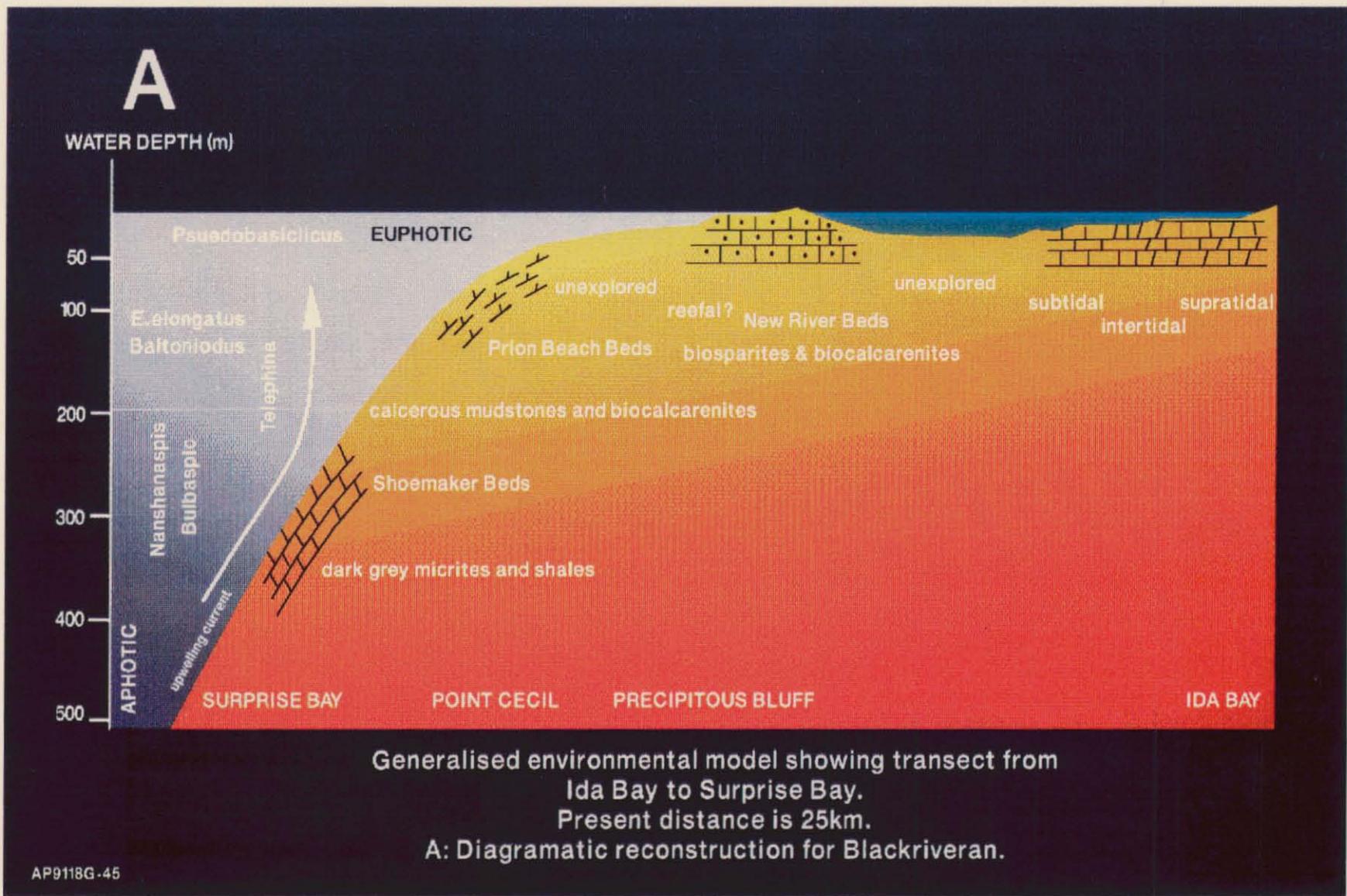
369044

22





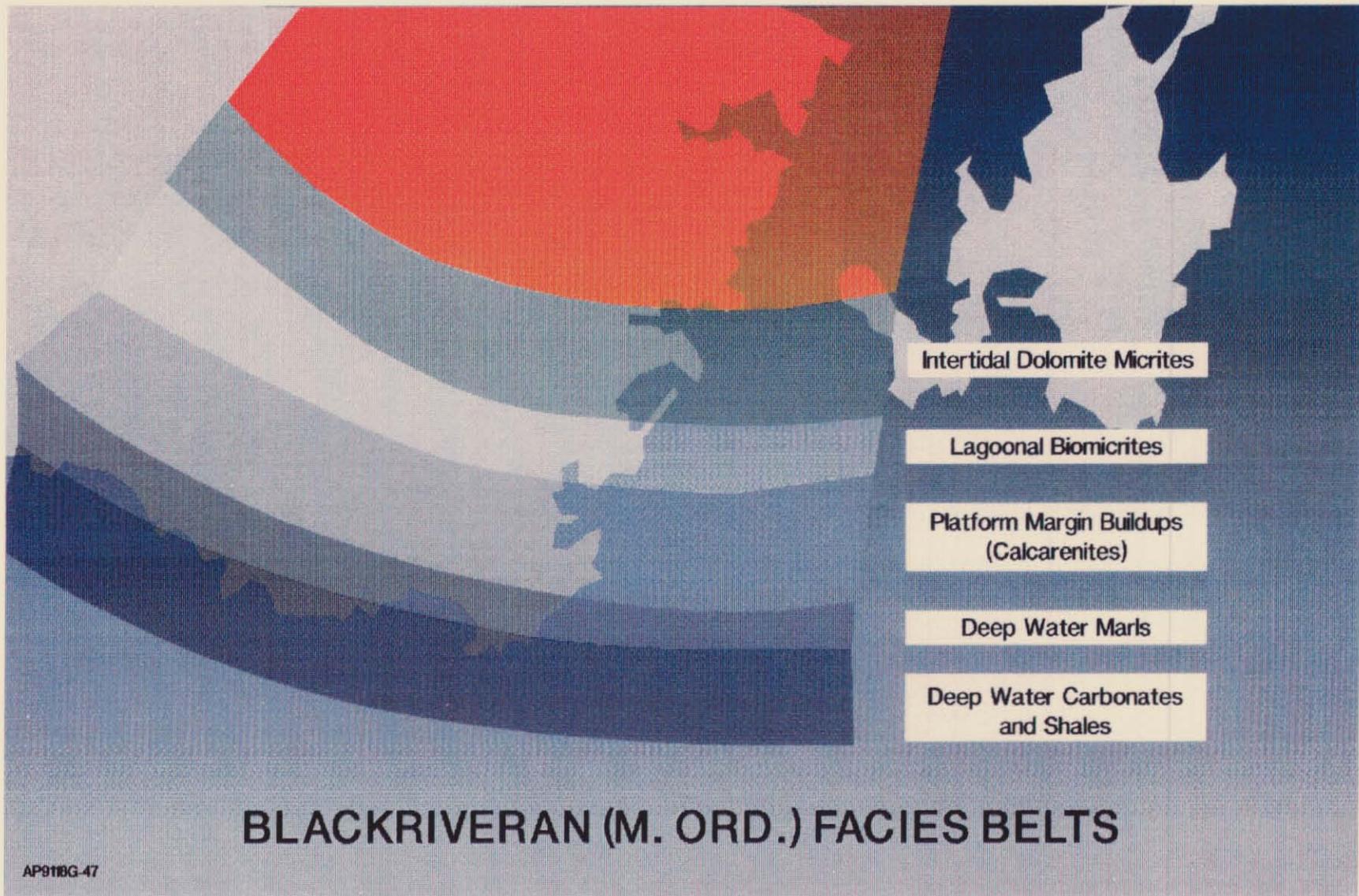




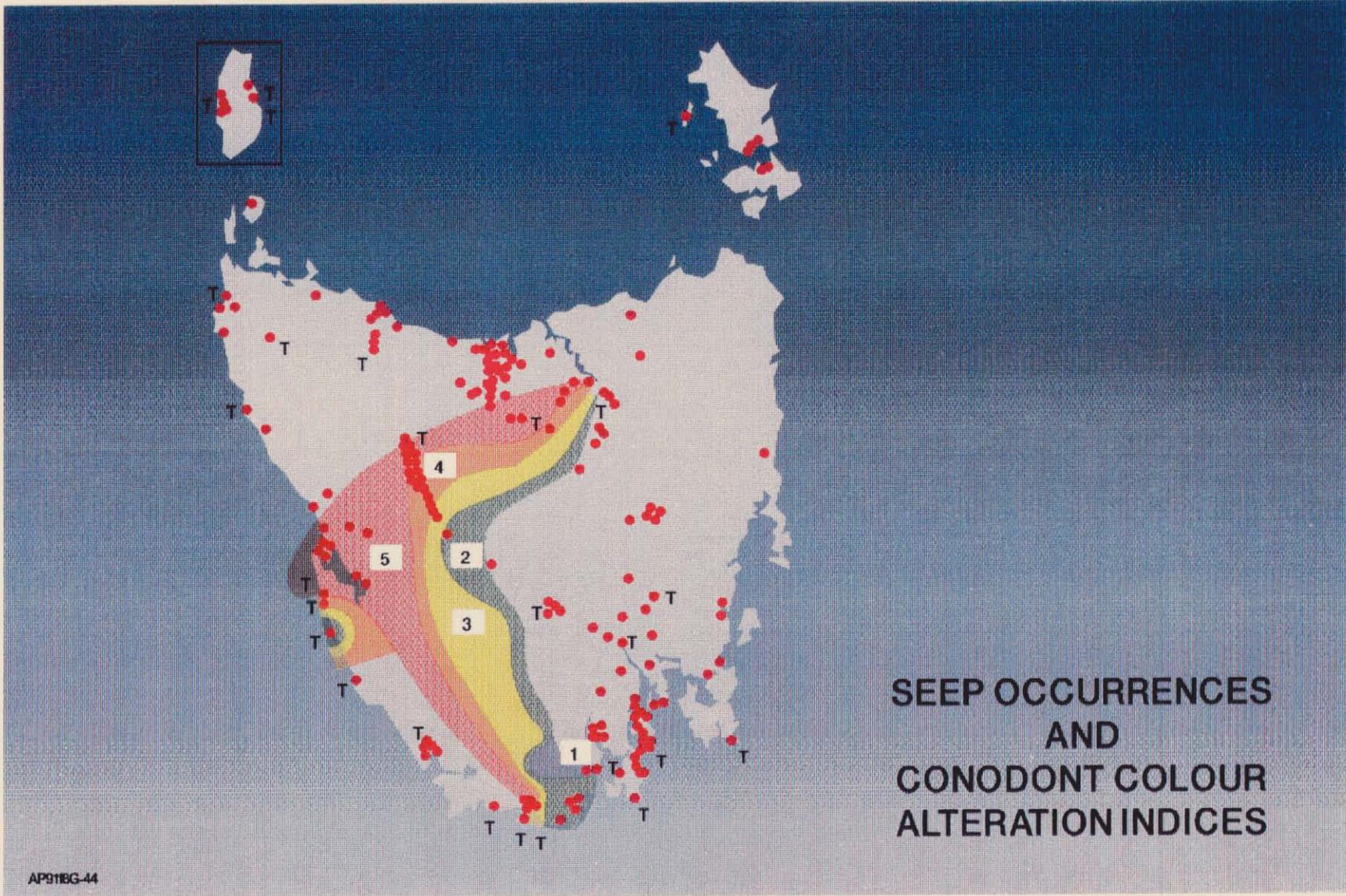
26

27

0048

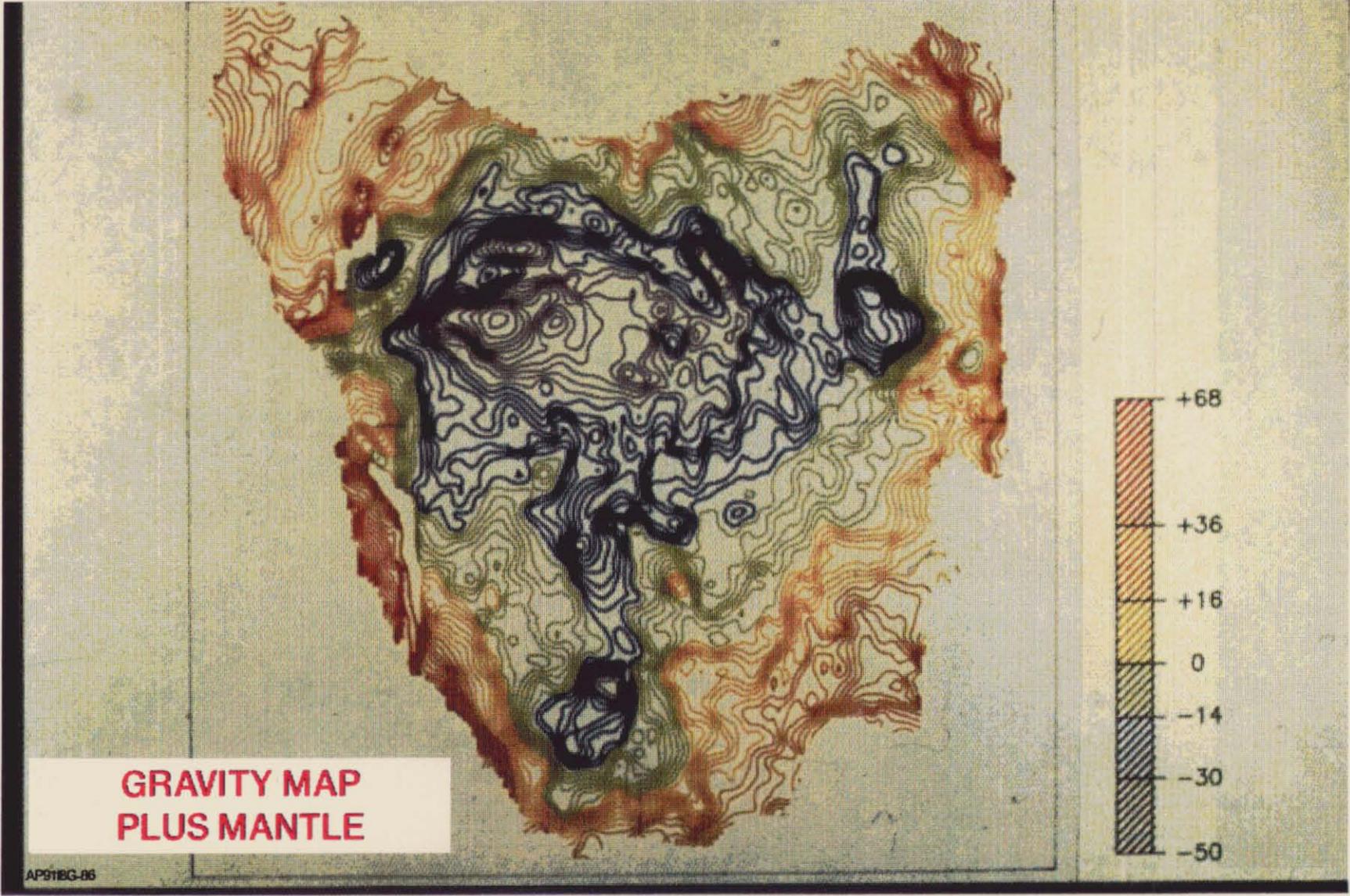


369049



**SEEP OCCURRENCES
AND
CONODONT COLOUR
ALTERATION INDICES**

AP91BG-44

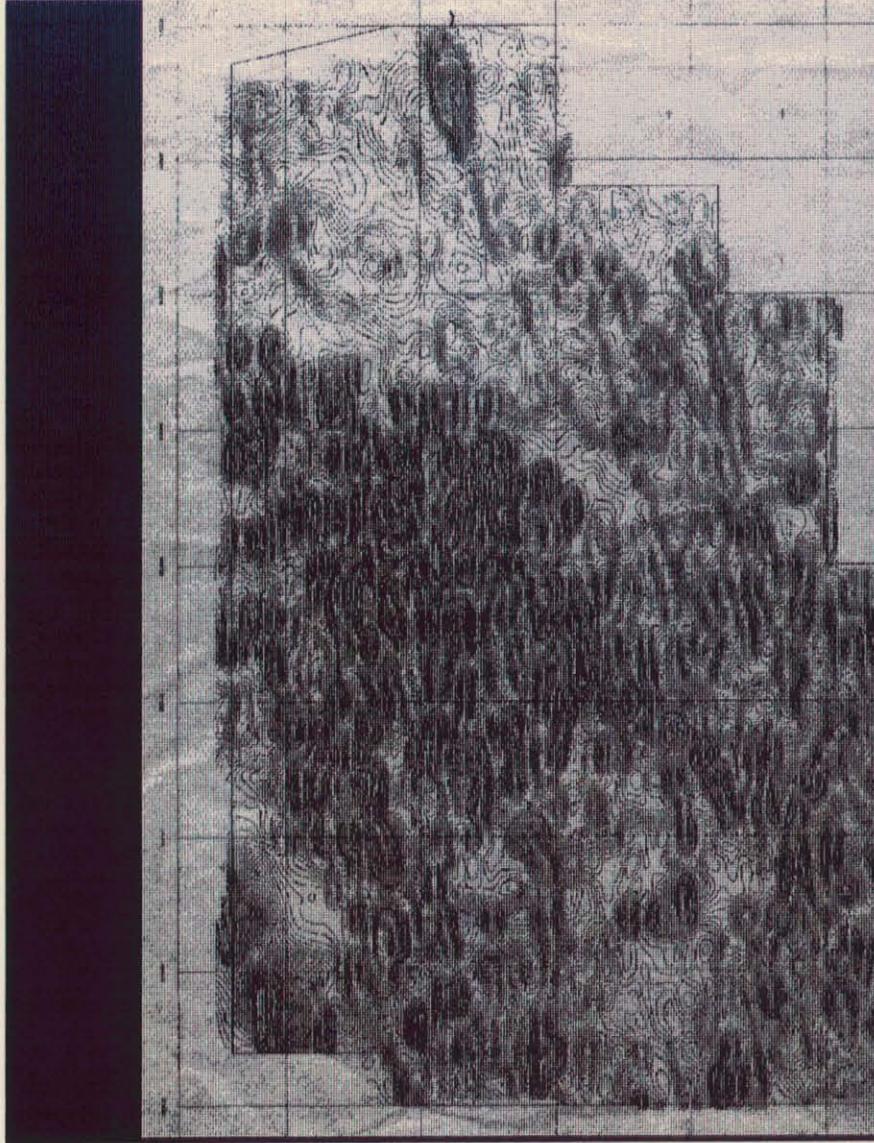


**GRAVITY MAP
PLUS MANTLE**

AP01EG-06

0051

369052



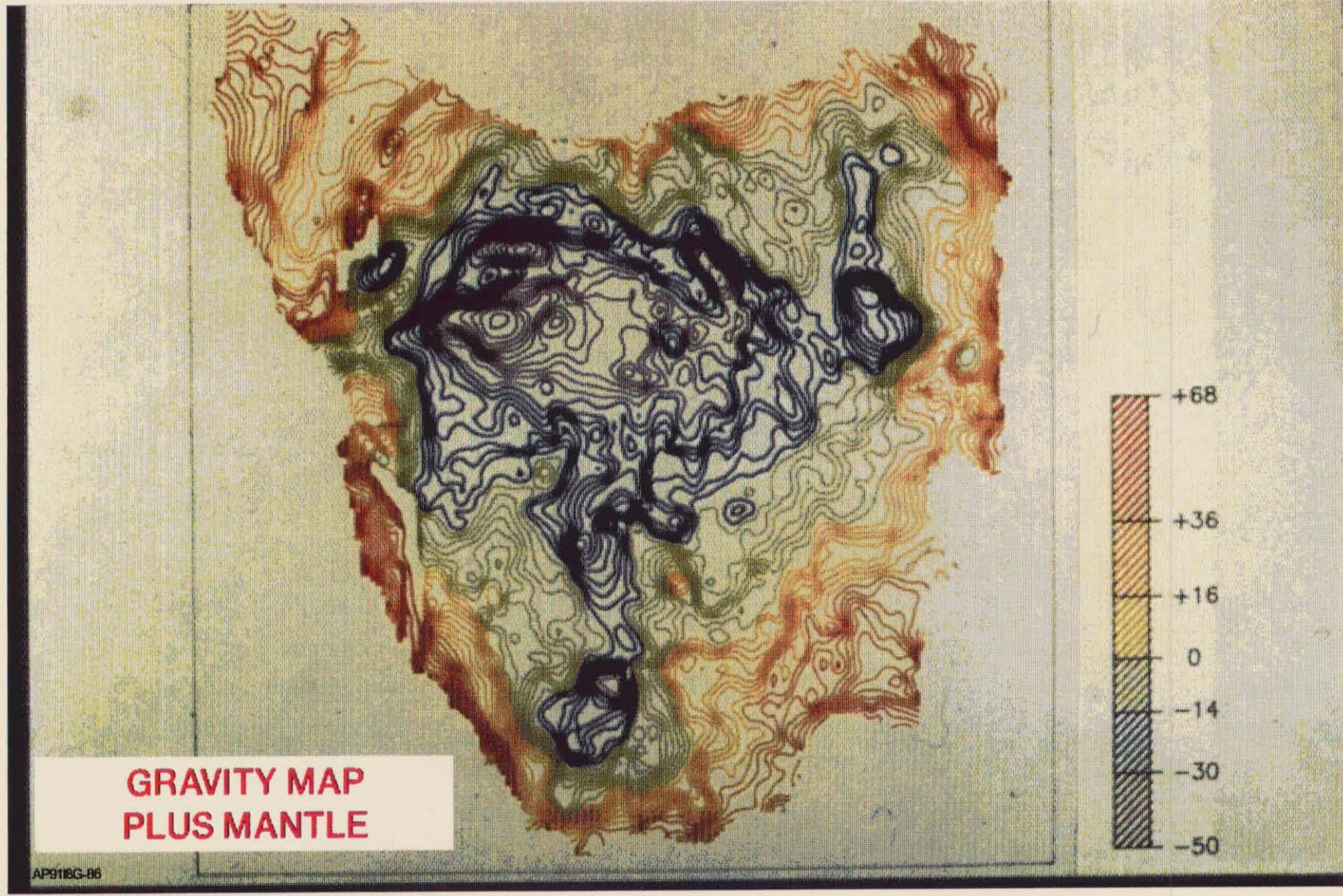
AIRBORNE MAGNETIC SURVEY NORTH TASMANIA BASIN



AP9118G-83

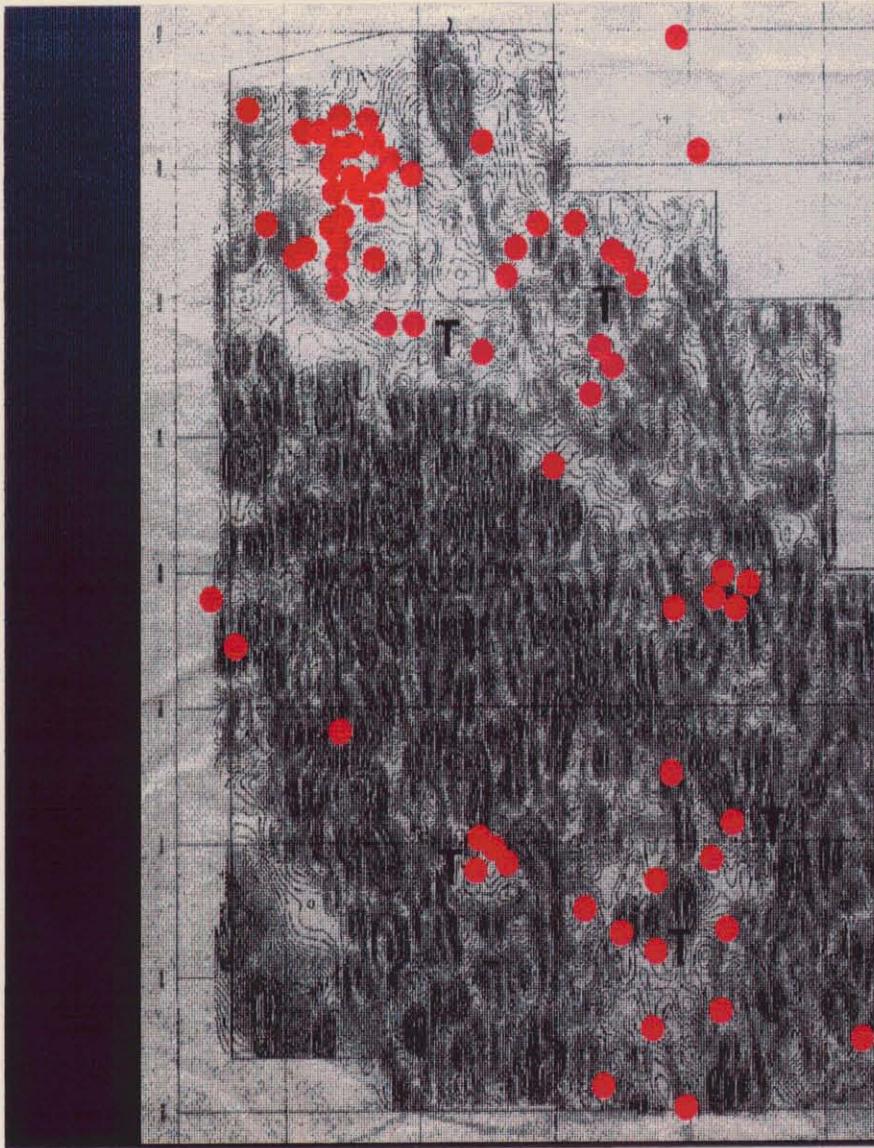
369053

0052







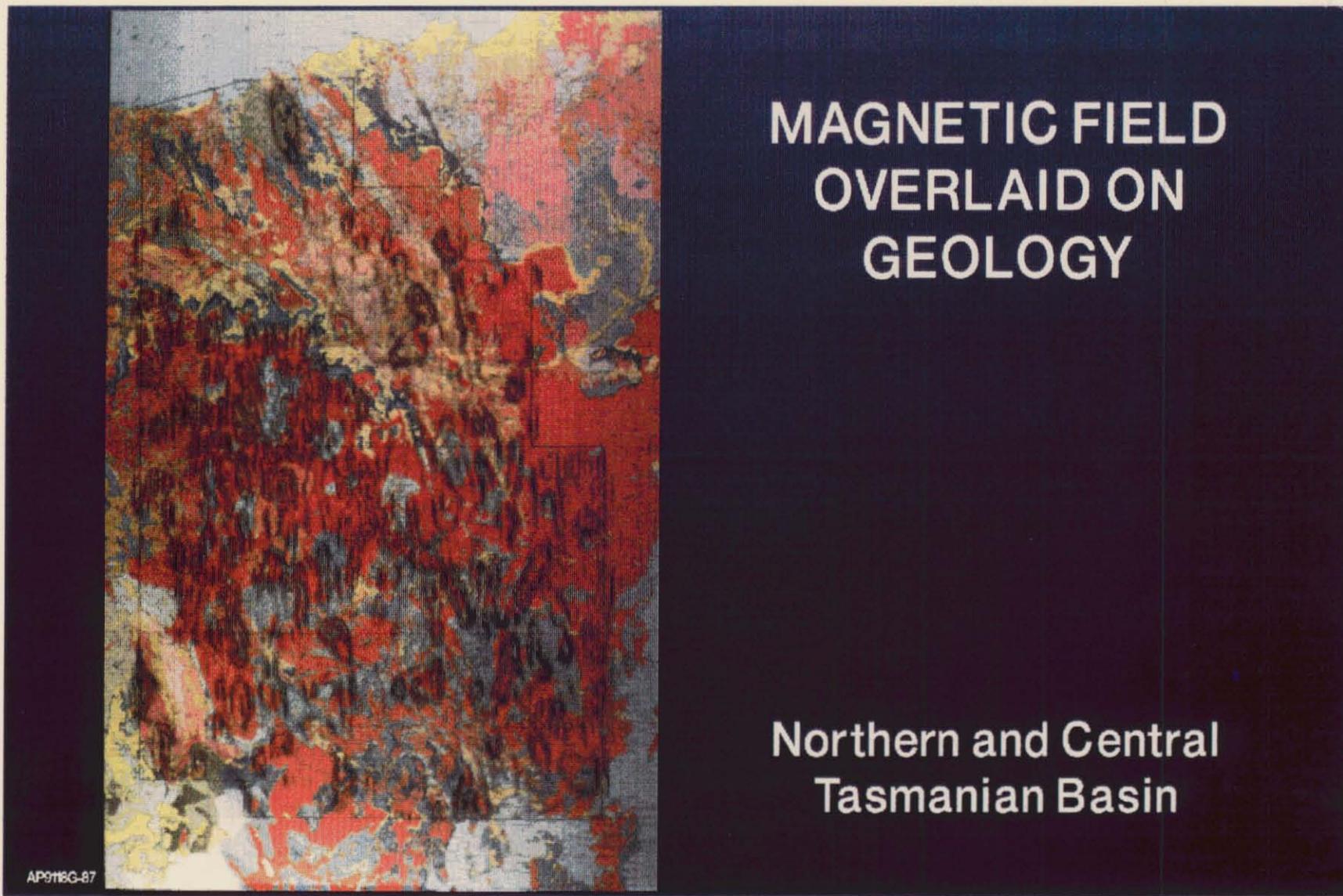


AIRBORNE MAGNETIC SURVEY NORTH TASMANIA BASIN AND SEEPS



AP9118G-83

35



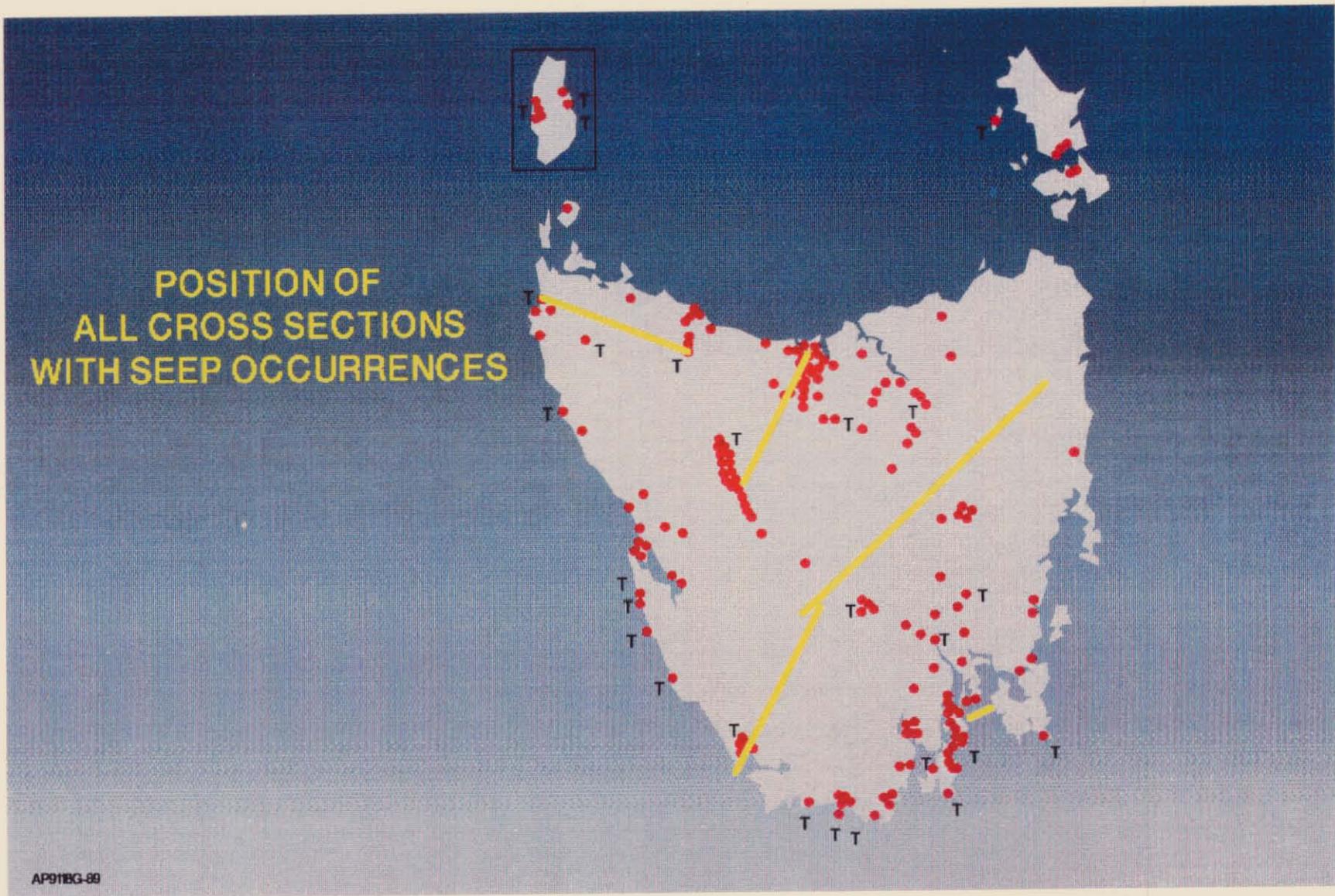
0056

369057

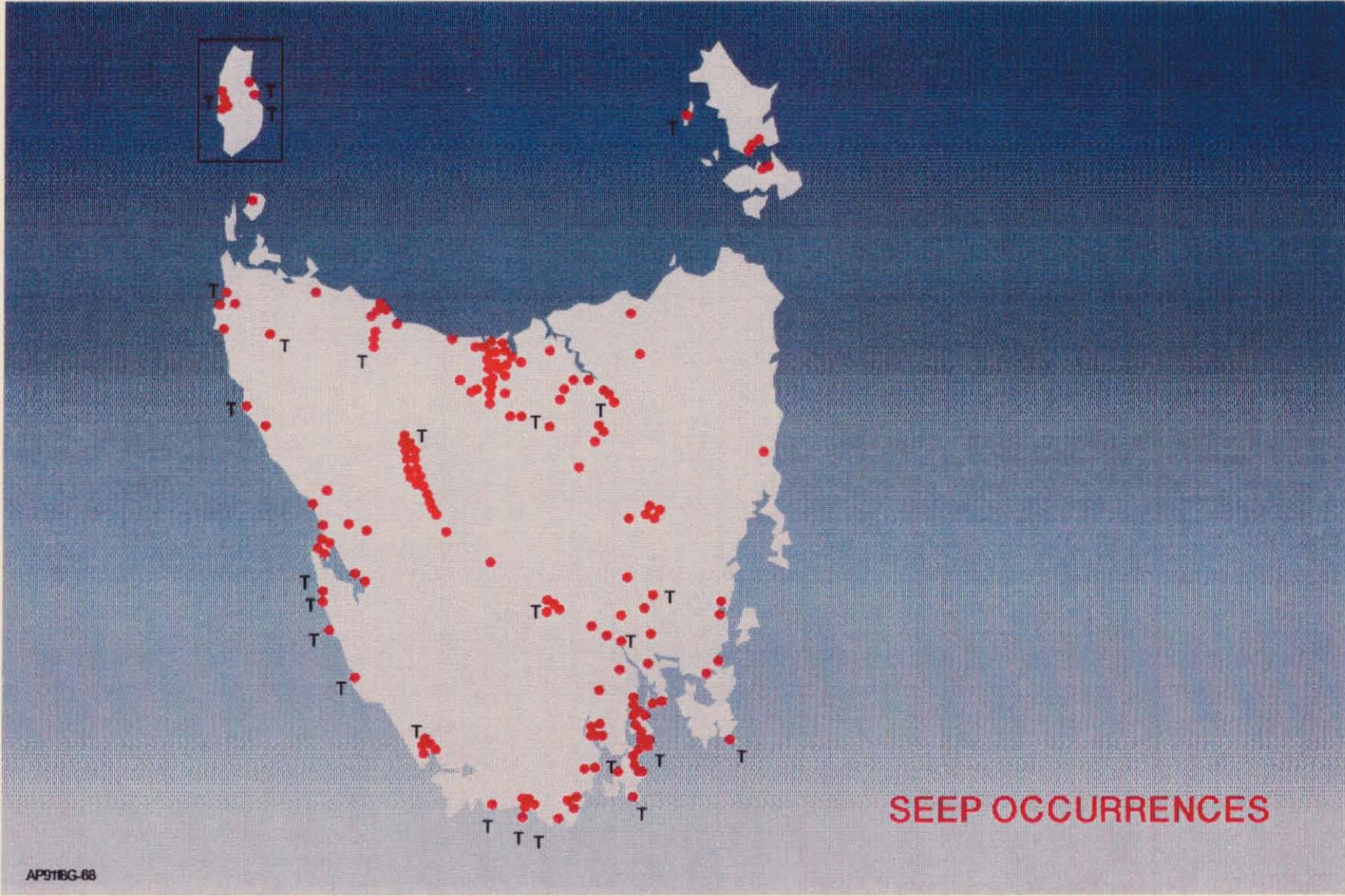
3



**POSITION OF
ALL CROSS SECTIONS
WITH SEEP OCCURRENCES**

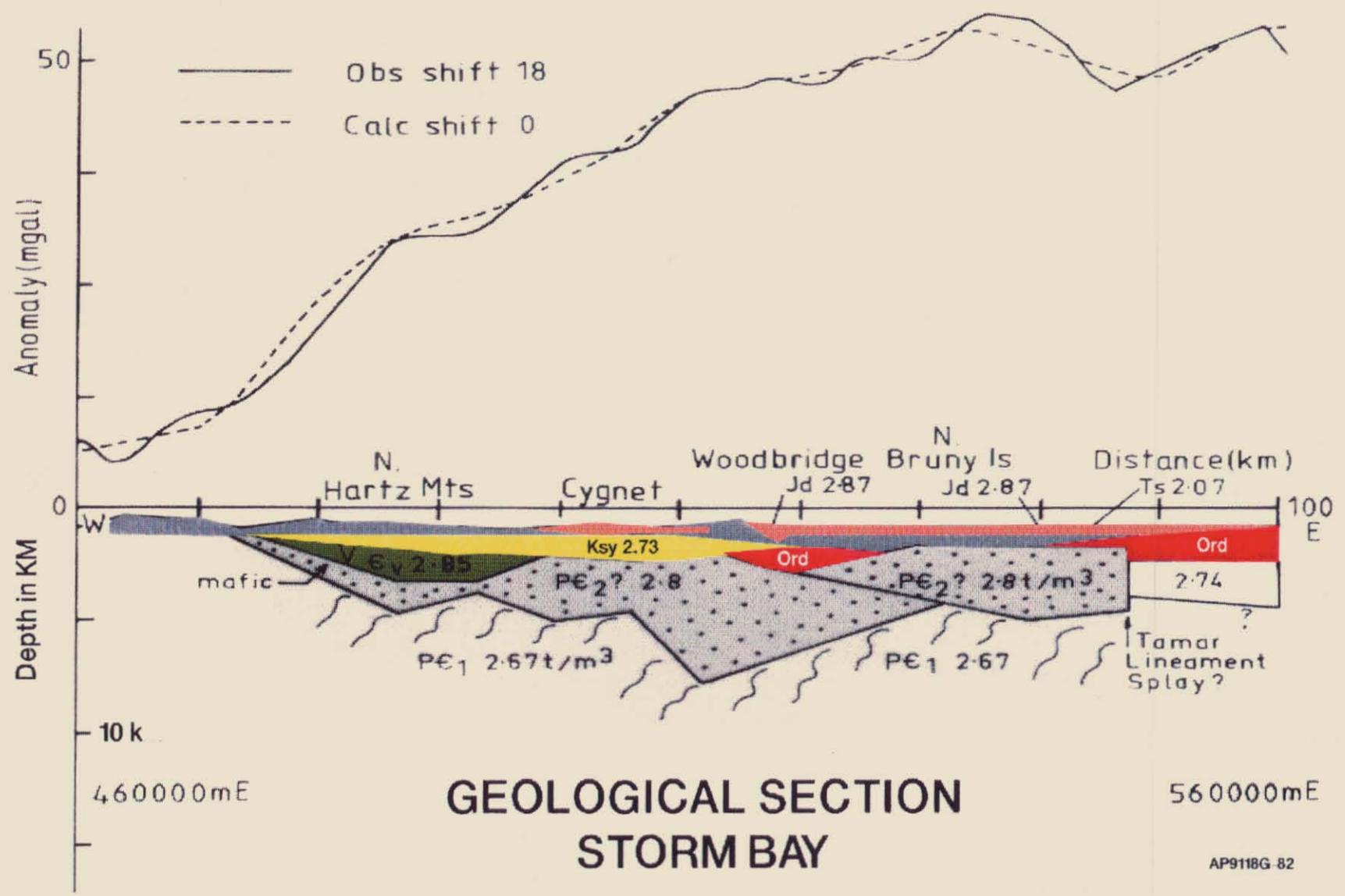


AP9118G-89



SEEP OCCURRENCES

AP918G-68



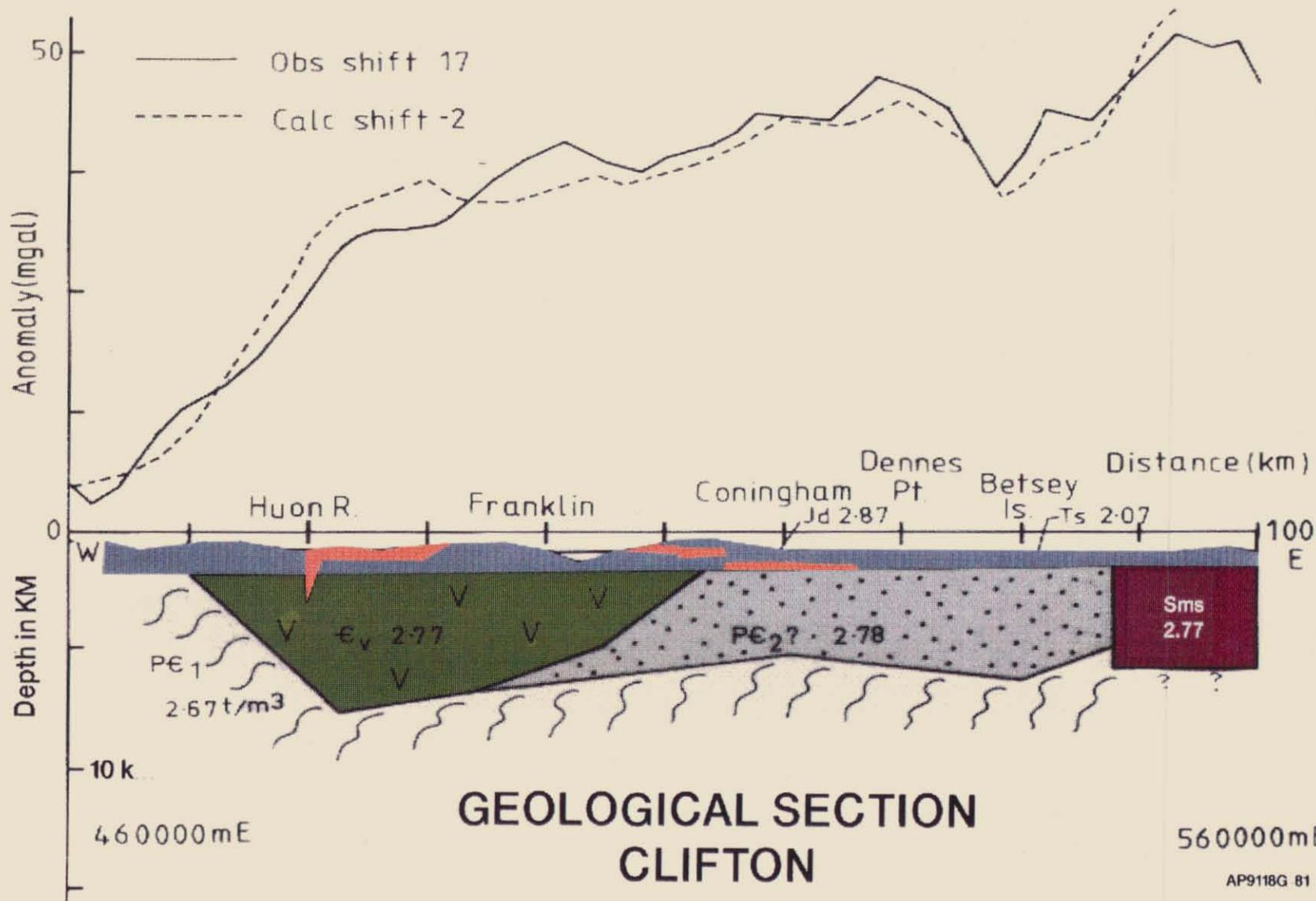
**GEOLOGICAL SECTION
STORM BAY**

460000mE

560000mE

AP9118G-82

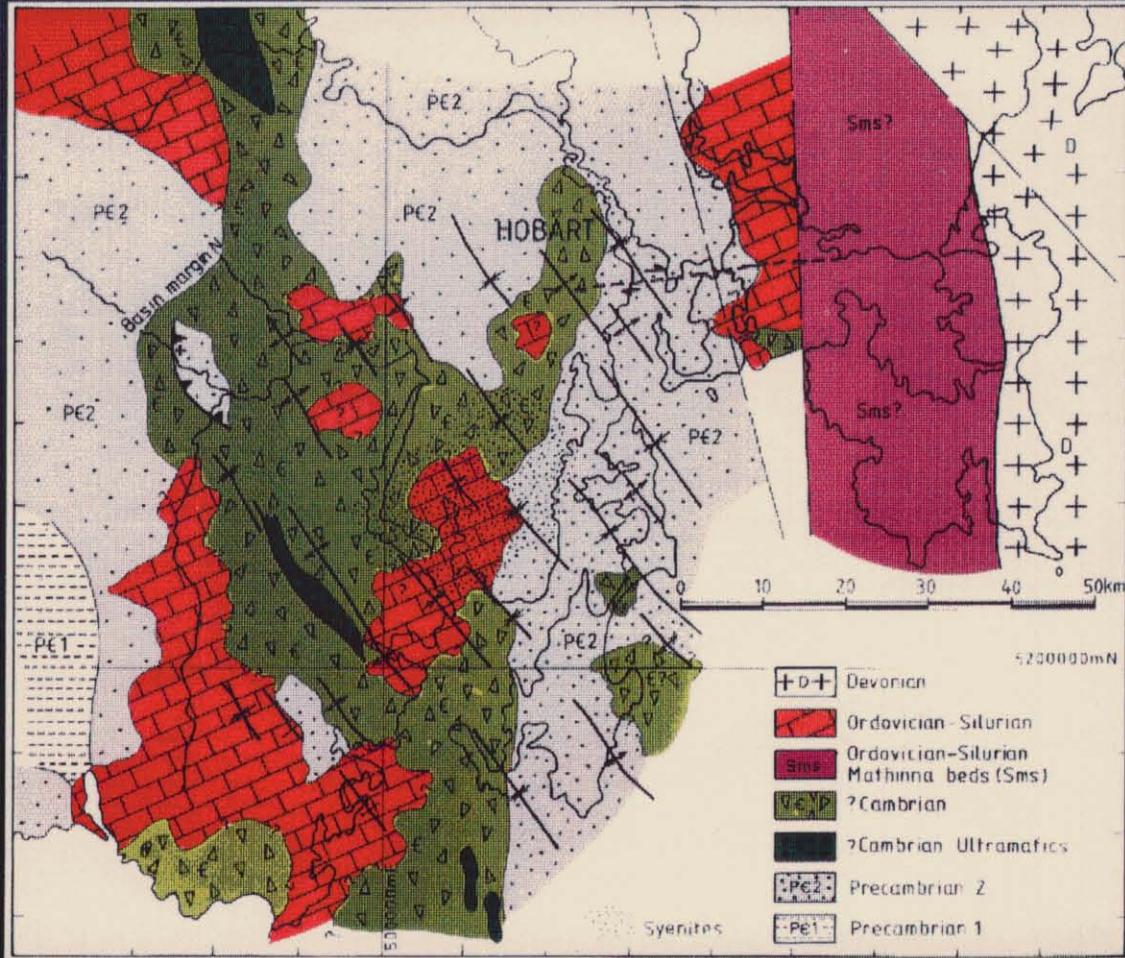
88



**GEOLOGICAL SECTION
CLIFTON**

560000mE

AP9118G 81



THE HIDDEN GEOLOGY OF SOUTHERN TASMANIA

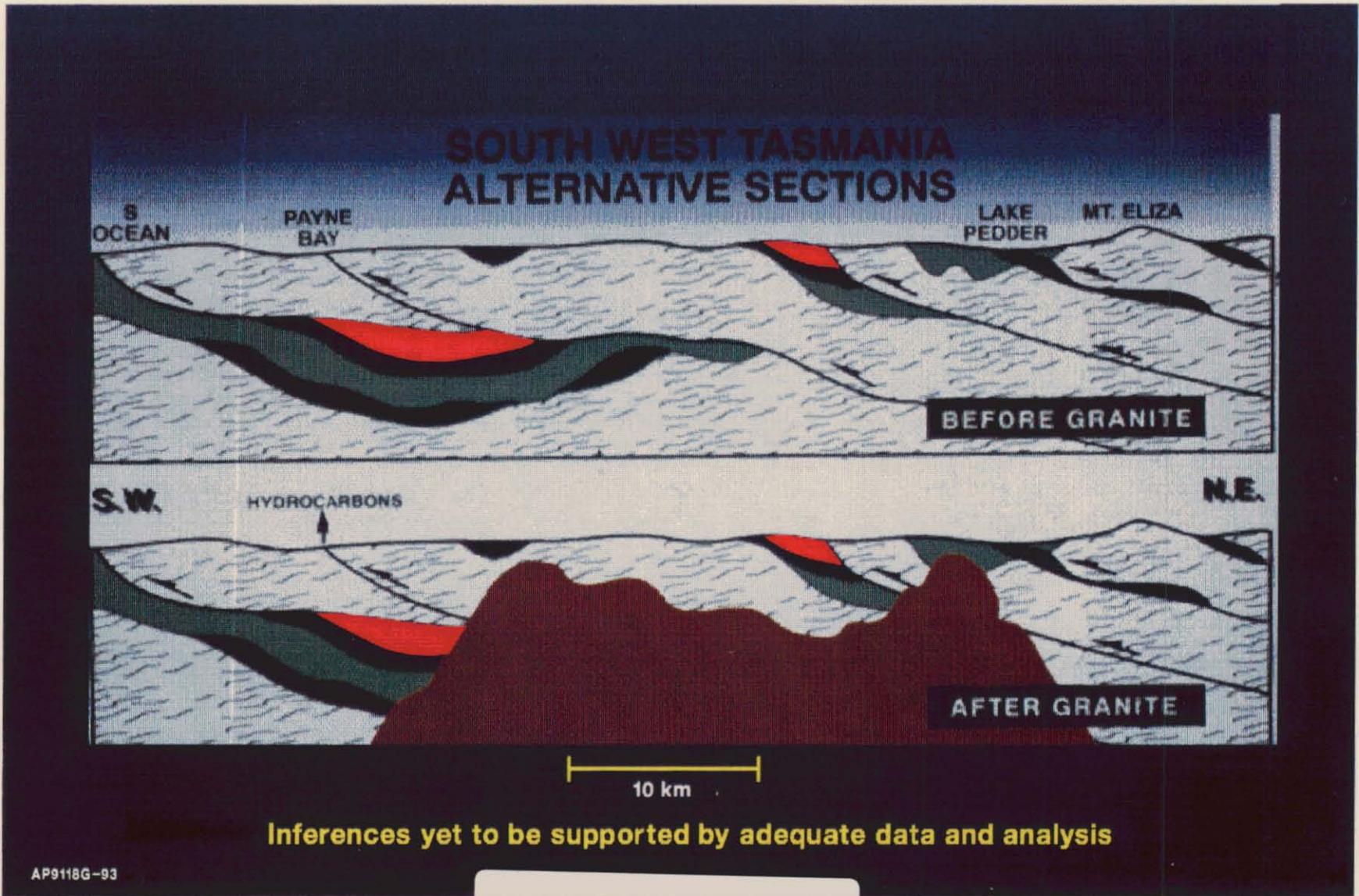
AP9118G-55

5 cm

077

17

0062



369063

SOUTH WEST TASMANIA



CONVENTIONAL SECTION

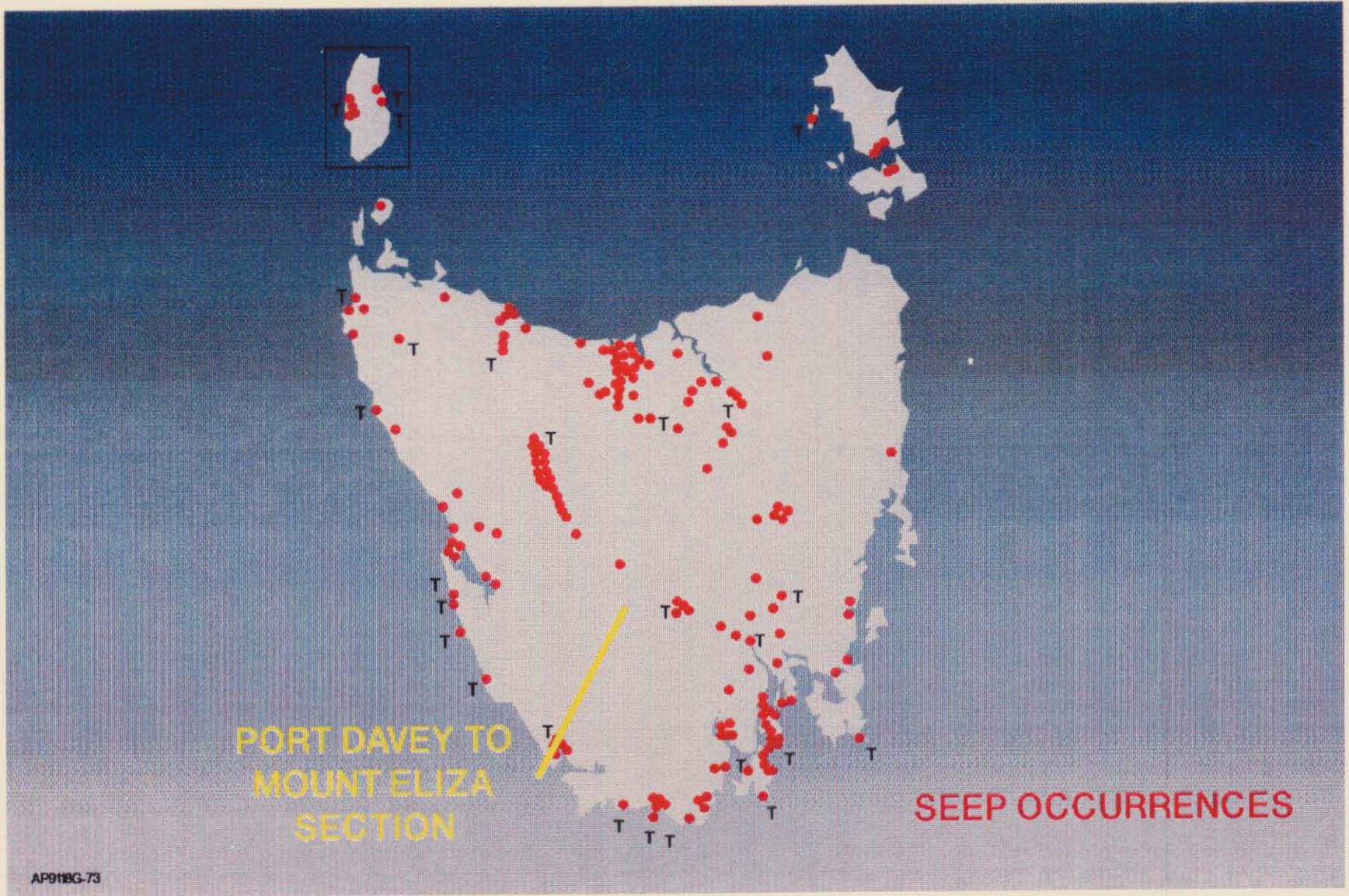
AP9118G-92

0063

369064

42

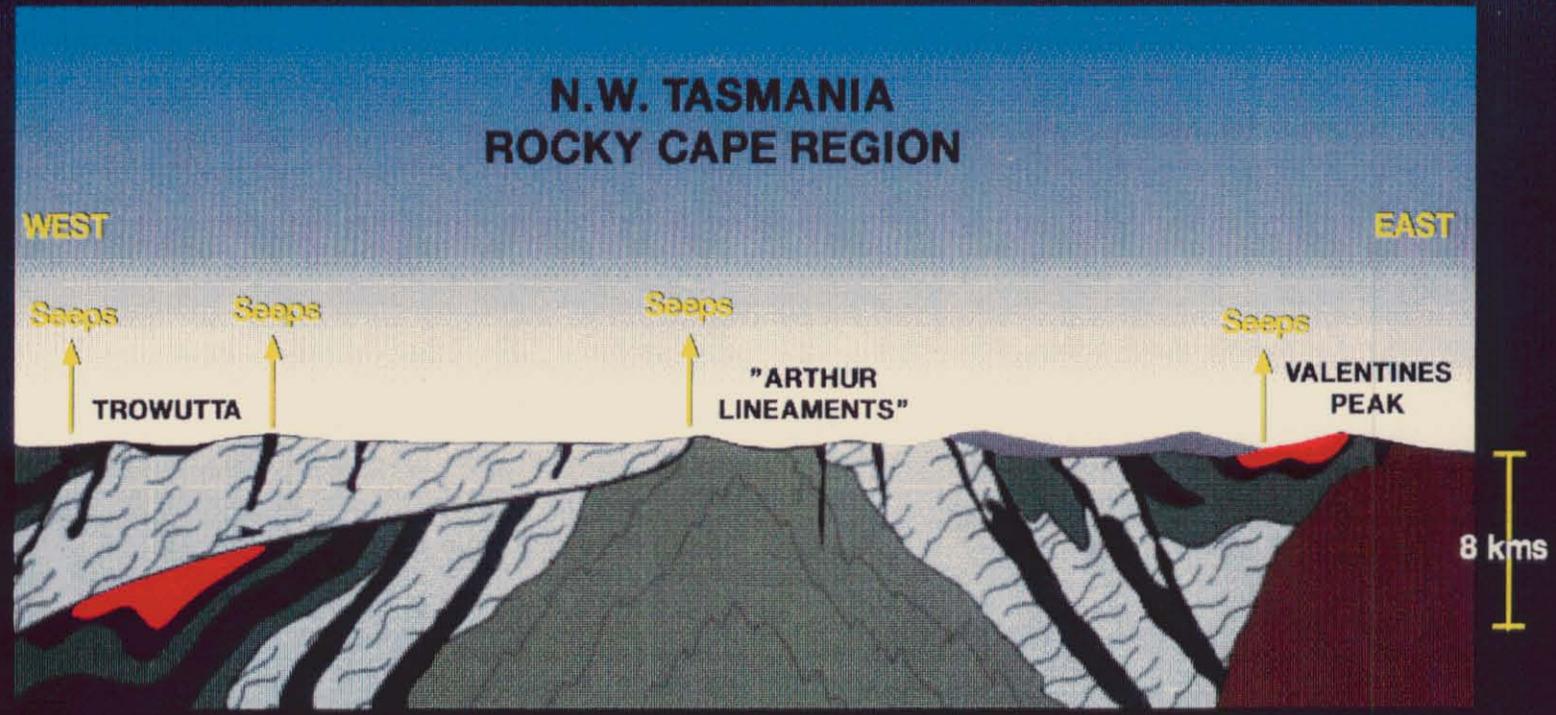
43



0064

369065

N.W. TASMANIA ROCKY CAPE REGION



10 kms
16 kms

5 cm

Based on interpretation of gravity and magnetic data.
(D. Leaman 1990)

AP9118G-94

7E

75

**SECTION OF NORTH WEST
ROCKY CAPE REGION**

SEEP OCCURRENCES

AP01BG-09



0066

369067

0067

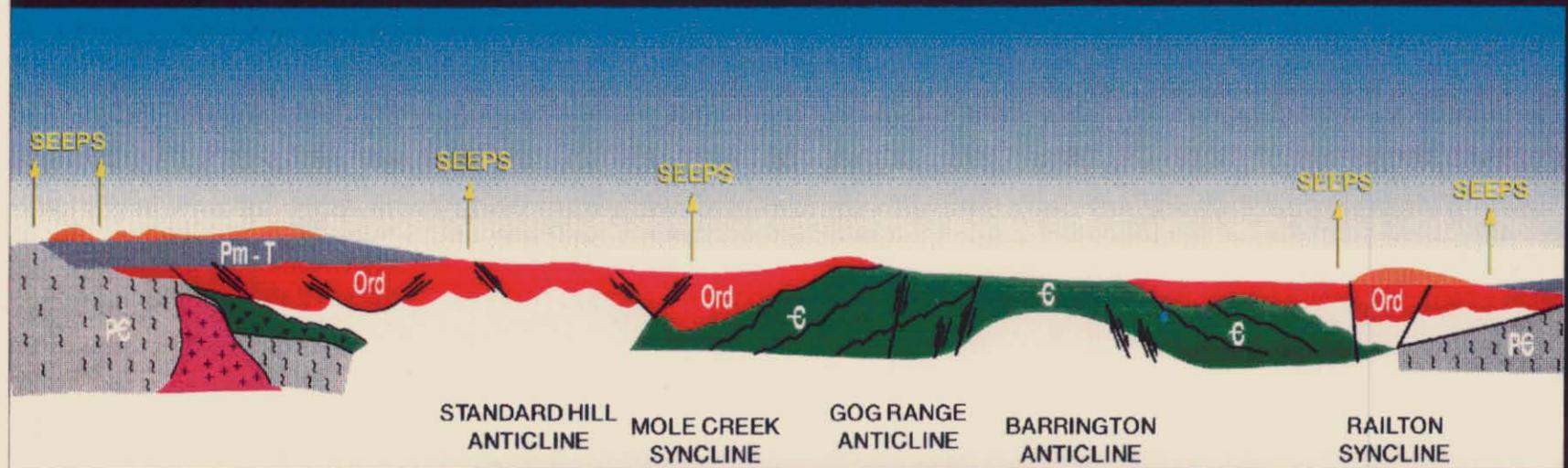
STYLISED SECTION THROUGH NORTH WEST DISPLAYING RELATIONSHIPS BETWEEN SEEPS AND GEOLOGY

(after I. B. Jennings)

SSW.

NNE.

BARN BLUFF WESTERN TIERS MERSEY RIVER MOLE CREEK GOG RANGE BEULAH STOODLEY RIVER MERSEY RIVER



STANDARD HILL ANTICLINE MOLE CREEK SYNCLINE GOG RANGE ANTICLINE BARRINGTON ANTICLINE RAILTON SYNCLINE

- | | |
|---|--|
|  Jurassic Dolerite |  Ordovician |
|  Permo - Triassic |  Cambrian |
|  Devonian Granite |  Young Pre - Cambrian |

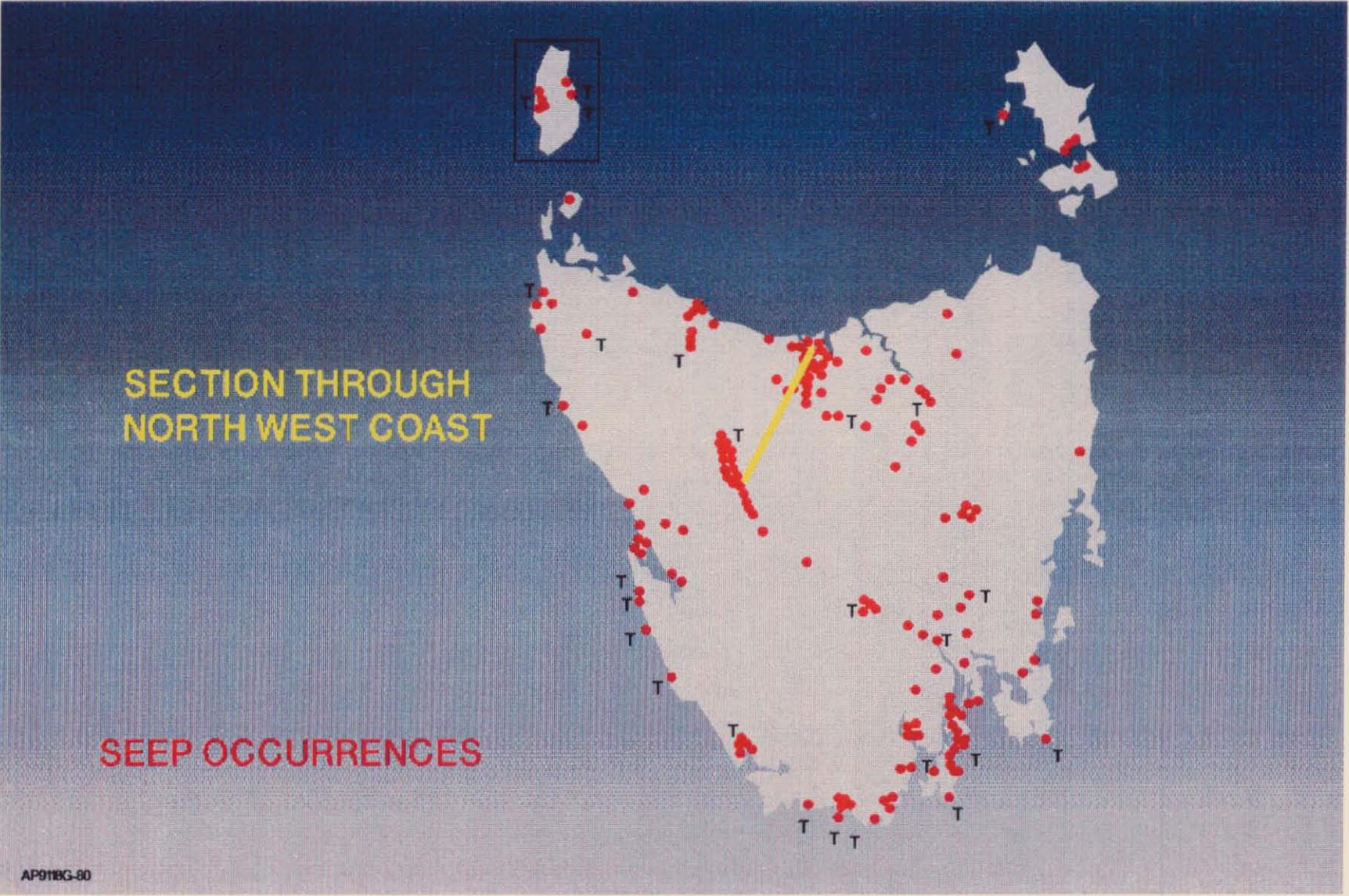
AP9118Q-79

369068

N6

7

0068



SECTION THROUGH
NORTH WEST COAST

SEEP OCCURRENCES

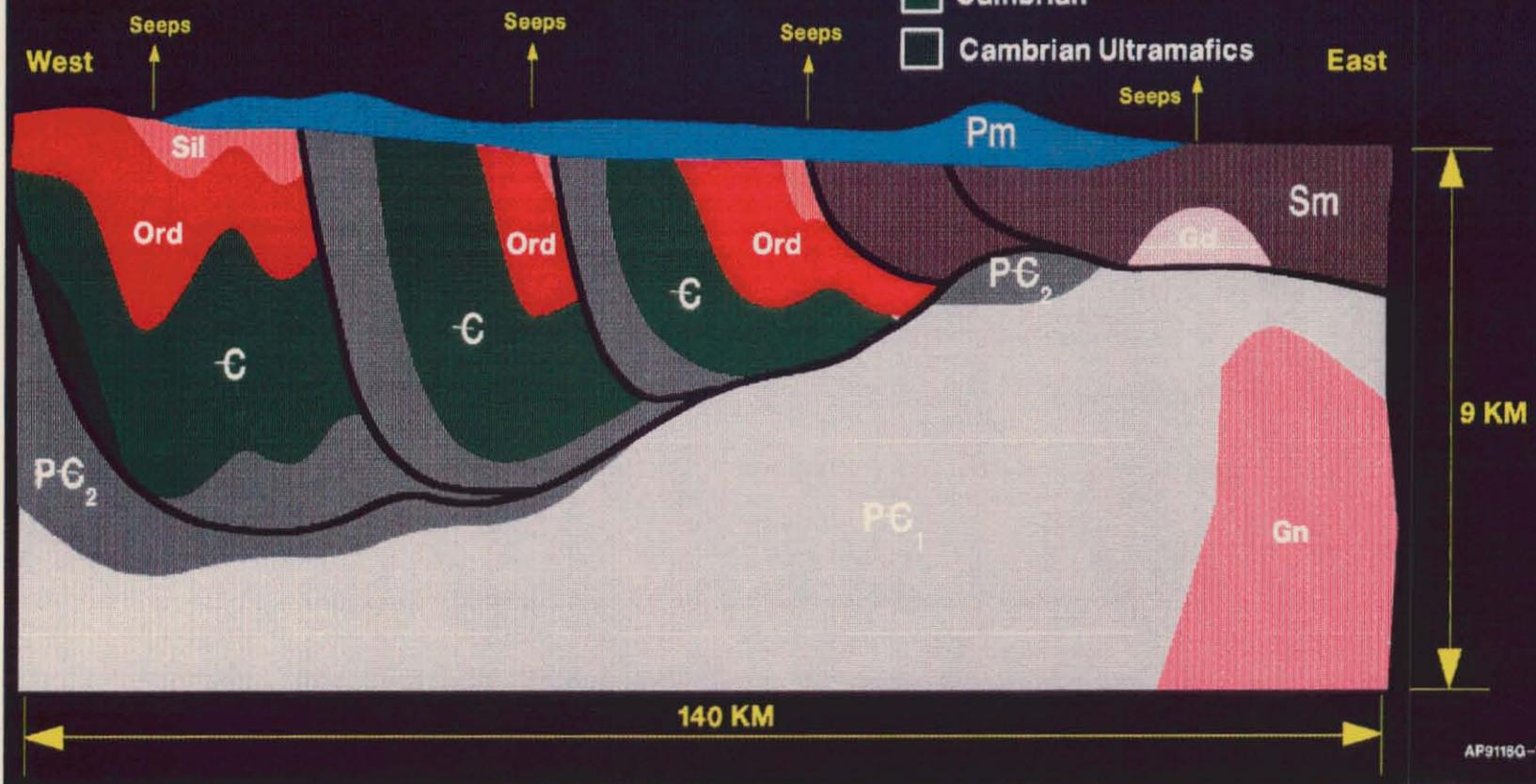
AP918G-80

369069

SUGGESTED RELATIONSHIPS AND STRUCTURAL STYLE ACROSS THE TASMANIAN BASIN

(D Leaman 1991)

- Permian
- Granodiorite
- Ord-silurian
- Devonian Granite
- Silurian
- Young Pre-Cambrian
- Ordovician
- Old Pre-Cambrian
- Cambrian
- Cambrian Ultramafics

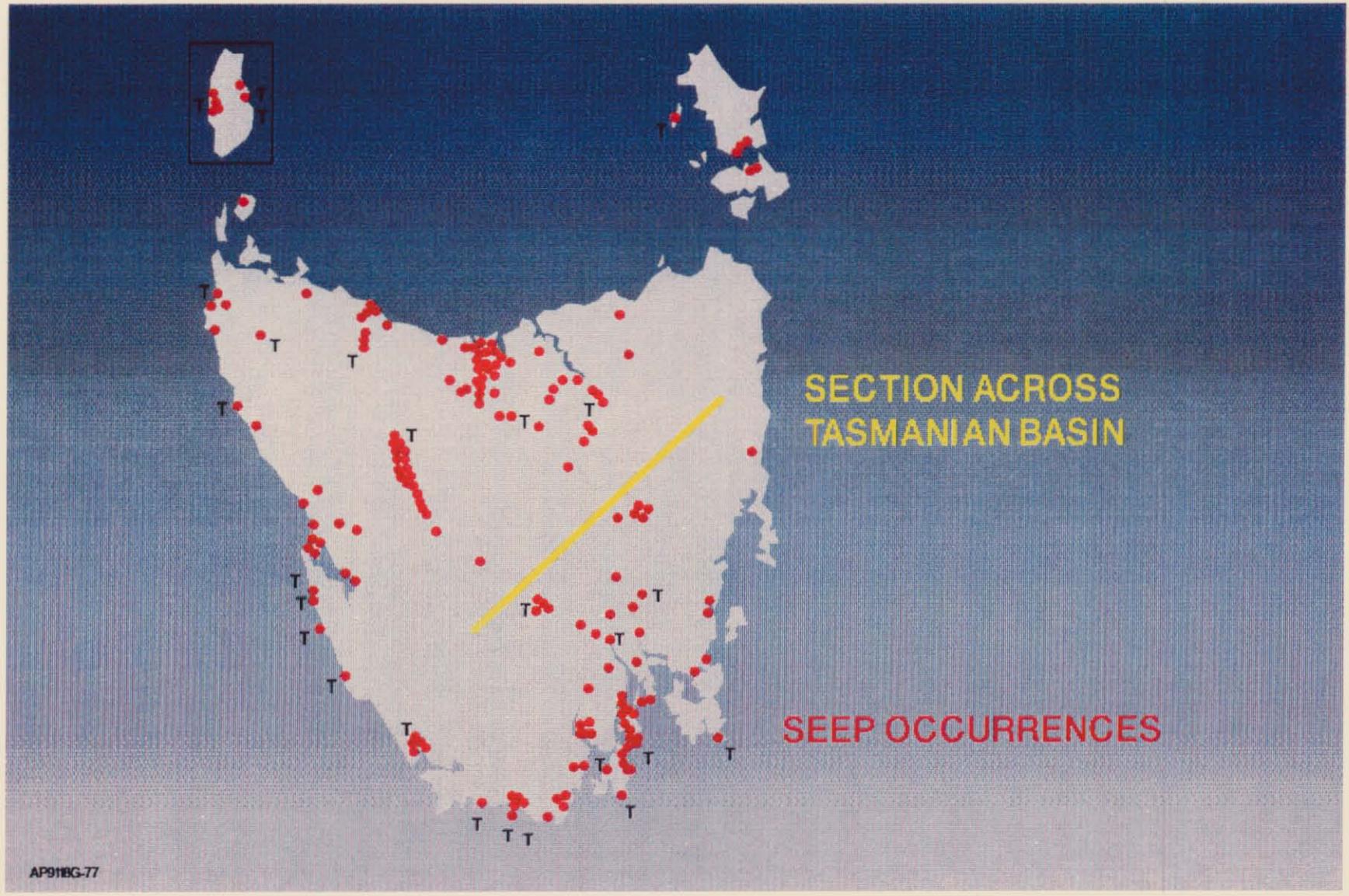


AP9118Q-79

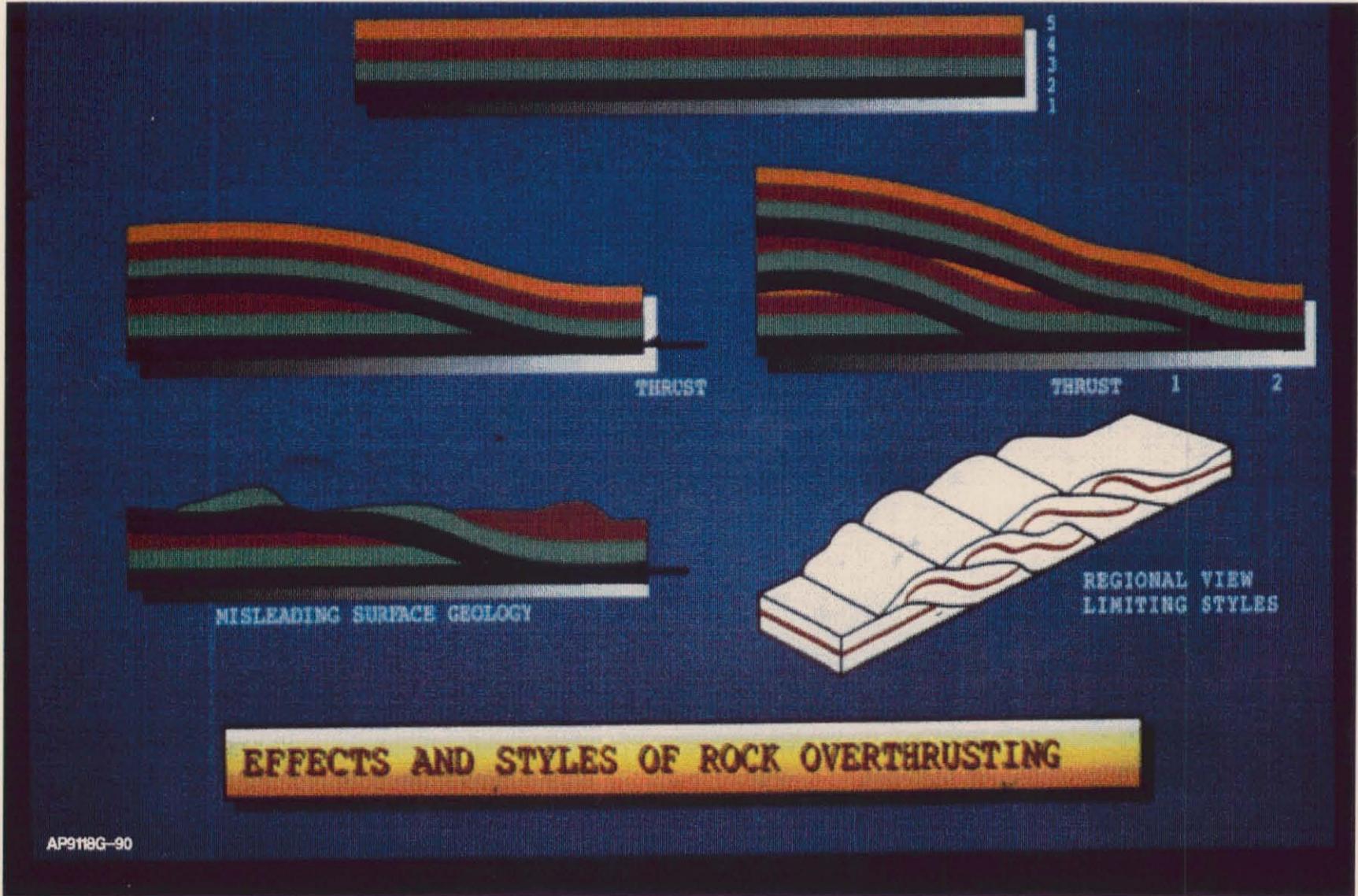
87

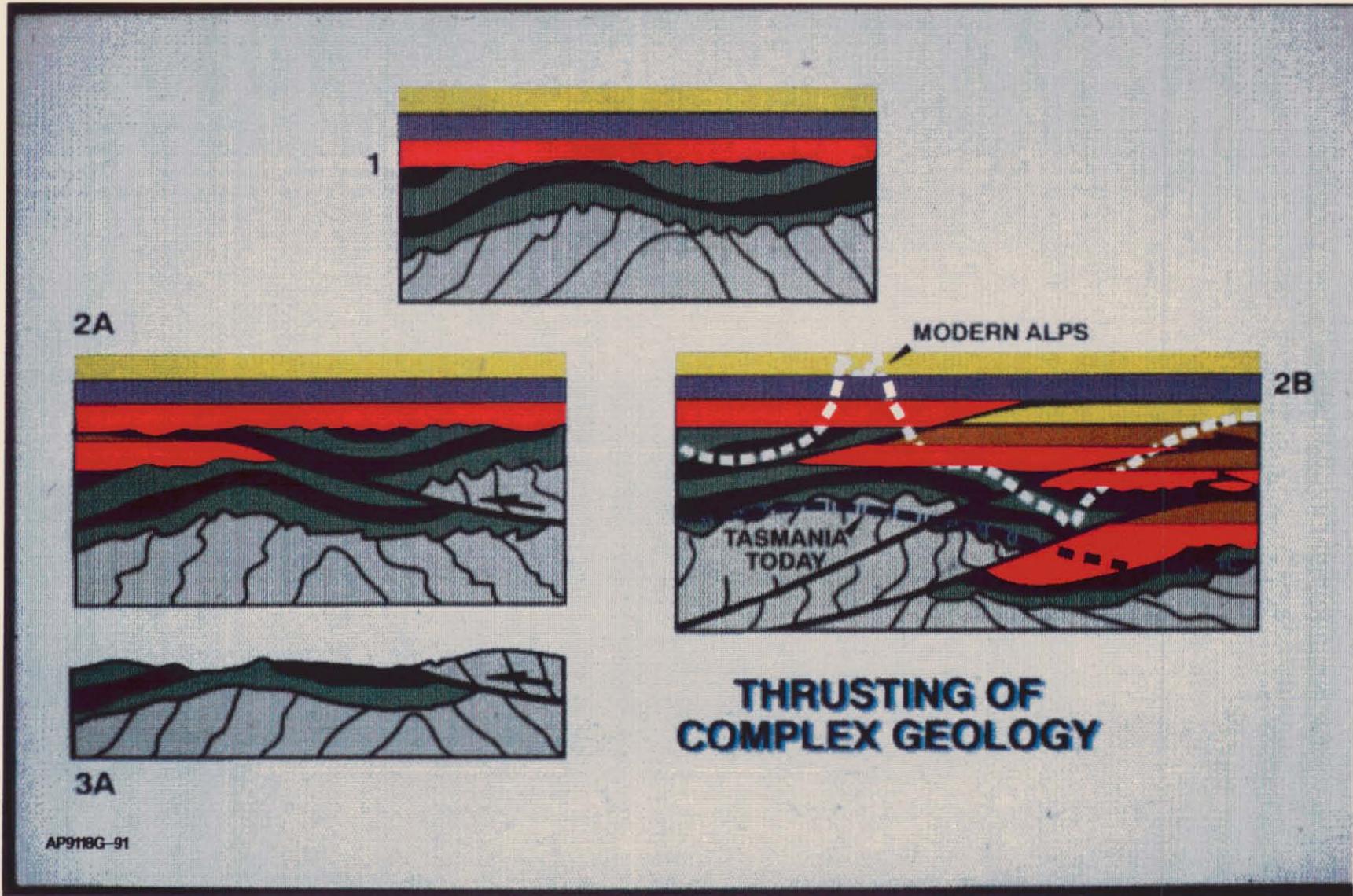
49

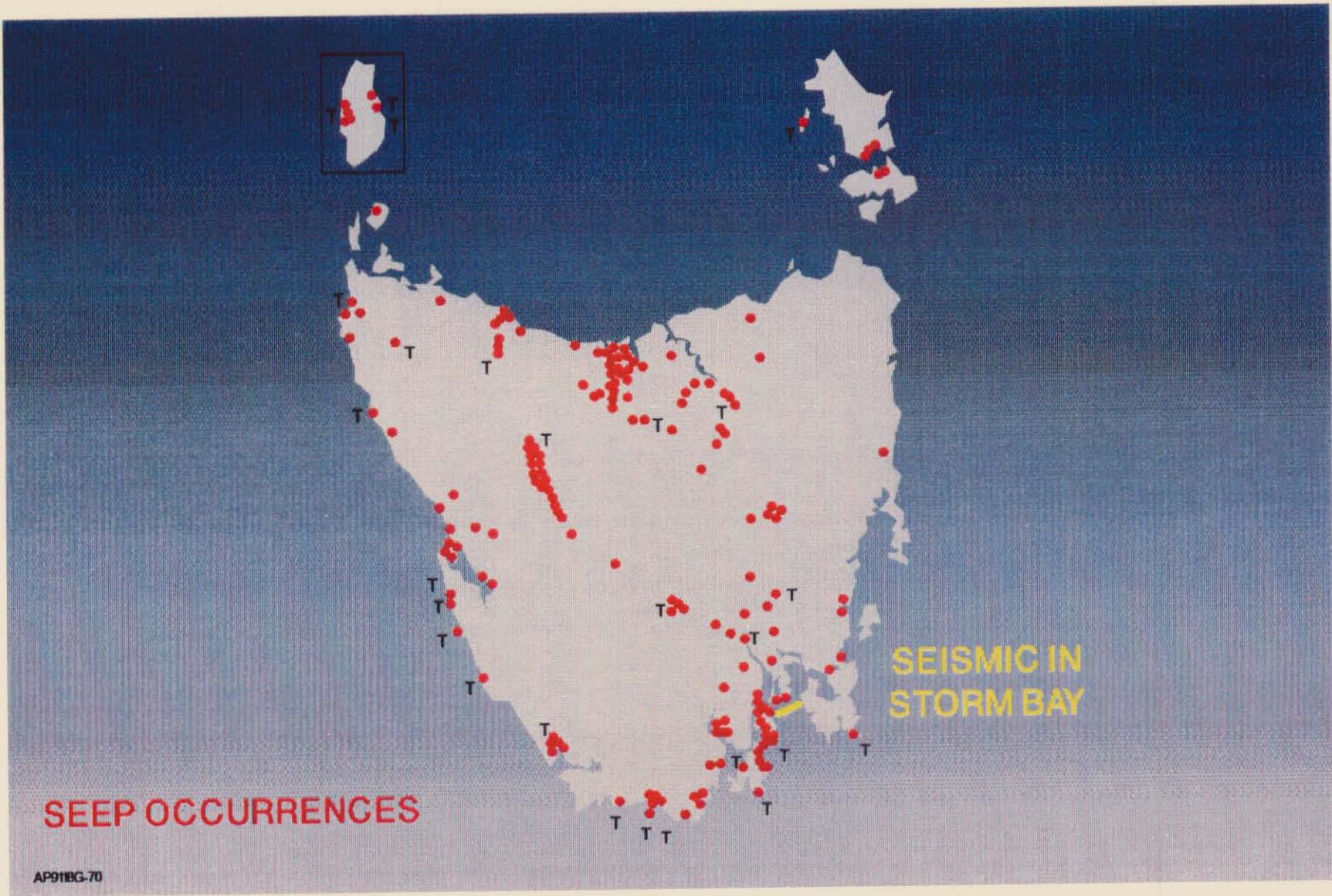
0070



369071



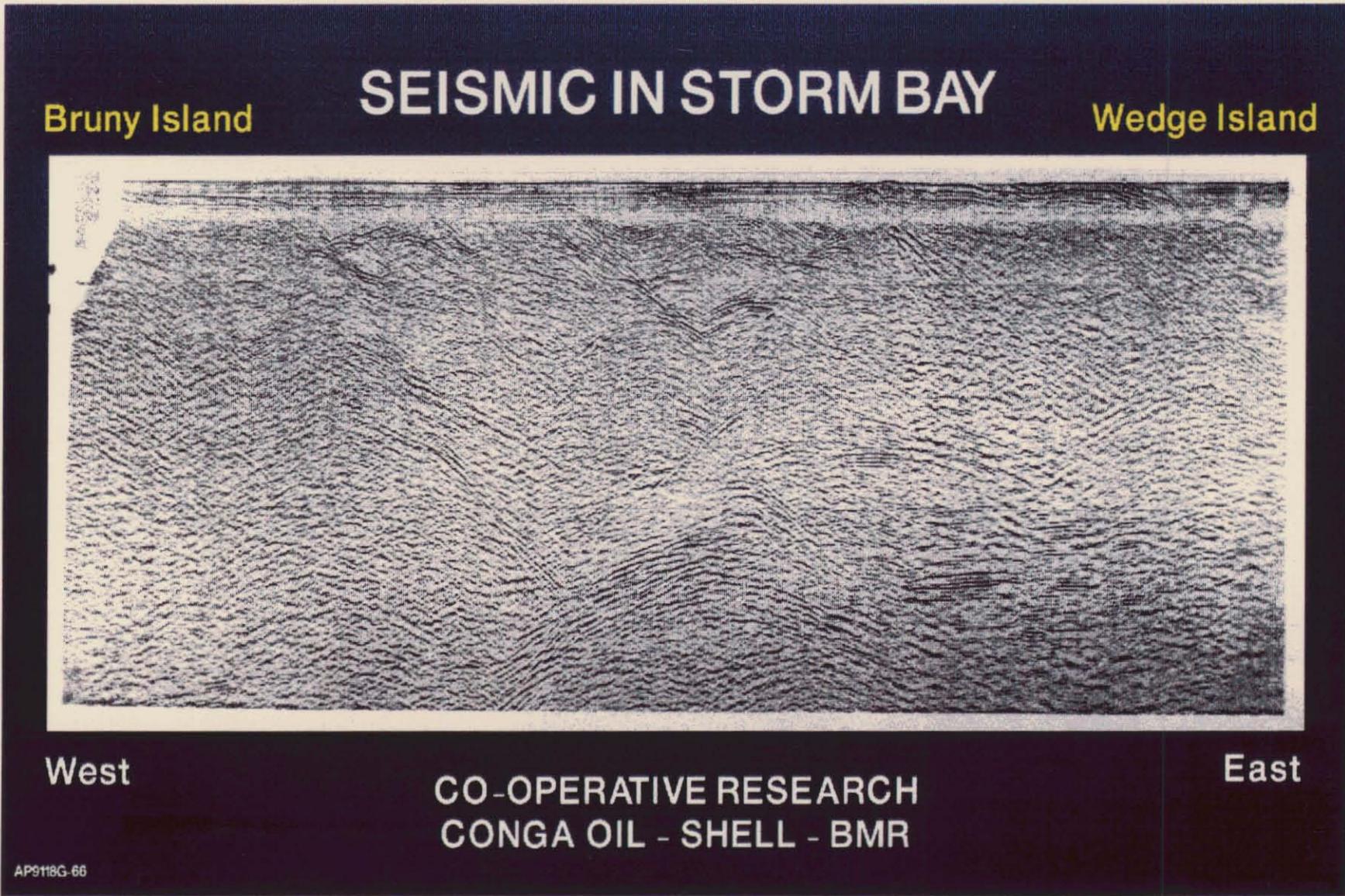




AP918G-70

53

0074



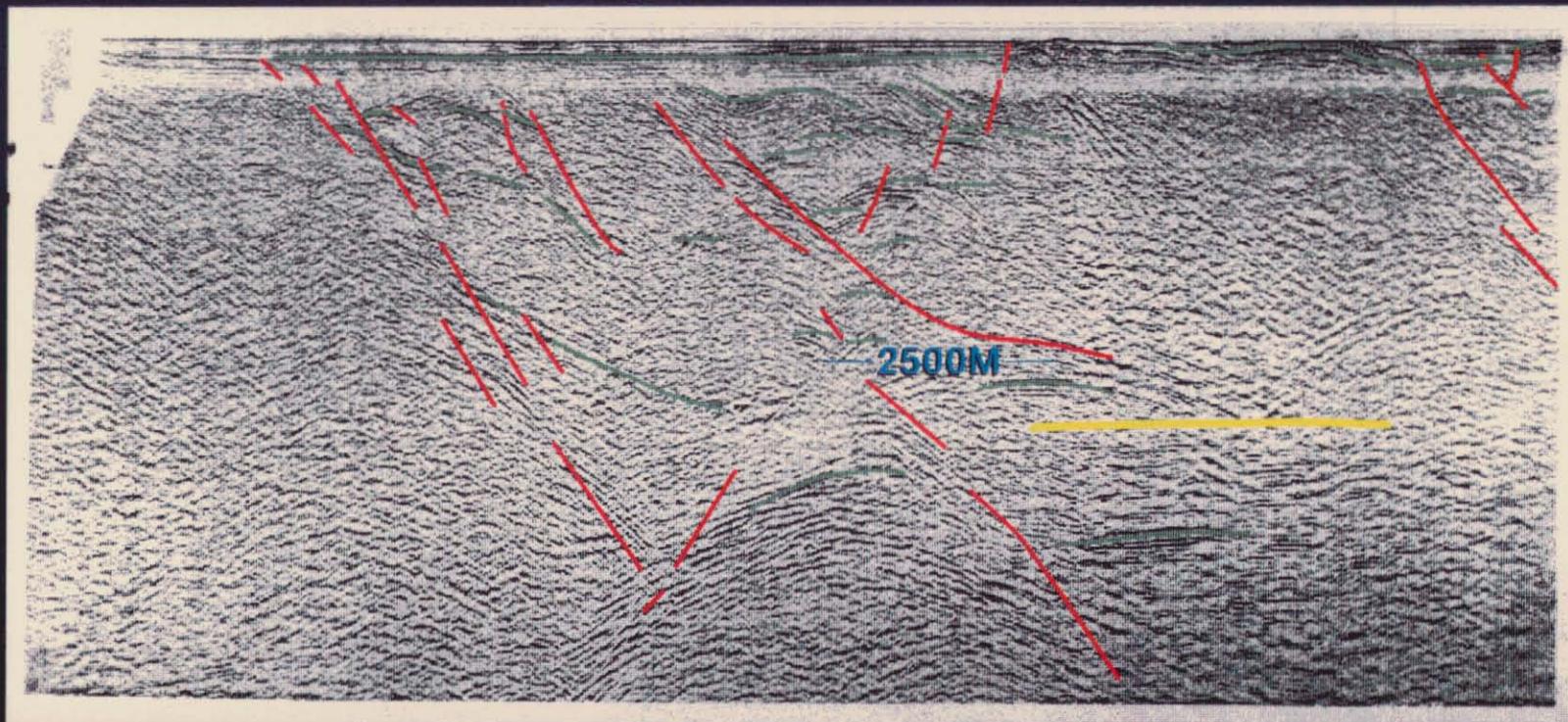
369075

0075

SEISMIC IN STORM BAY

Bruny Island

Wedge Island



Depth

Faults

Thrust

Horizons

West

East

PRELIMINARY INTERPRETATION

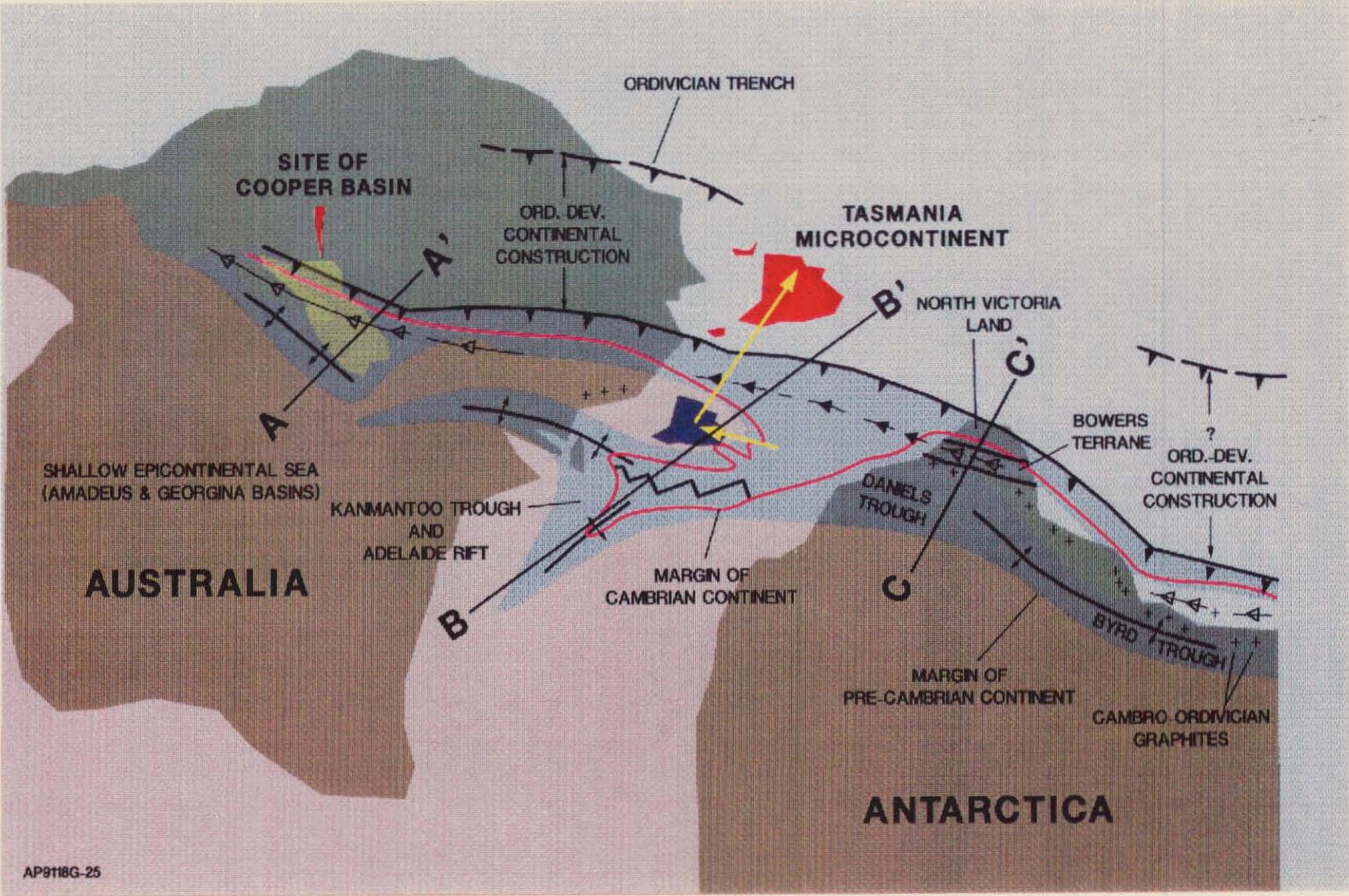
AP9118G-67

369076

5L

55

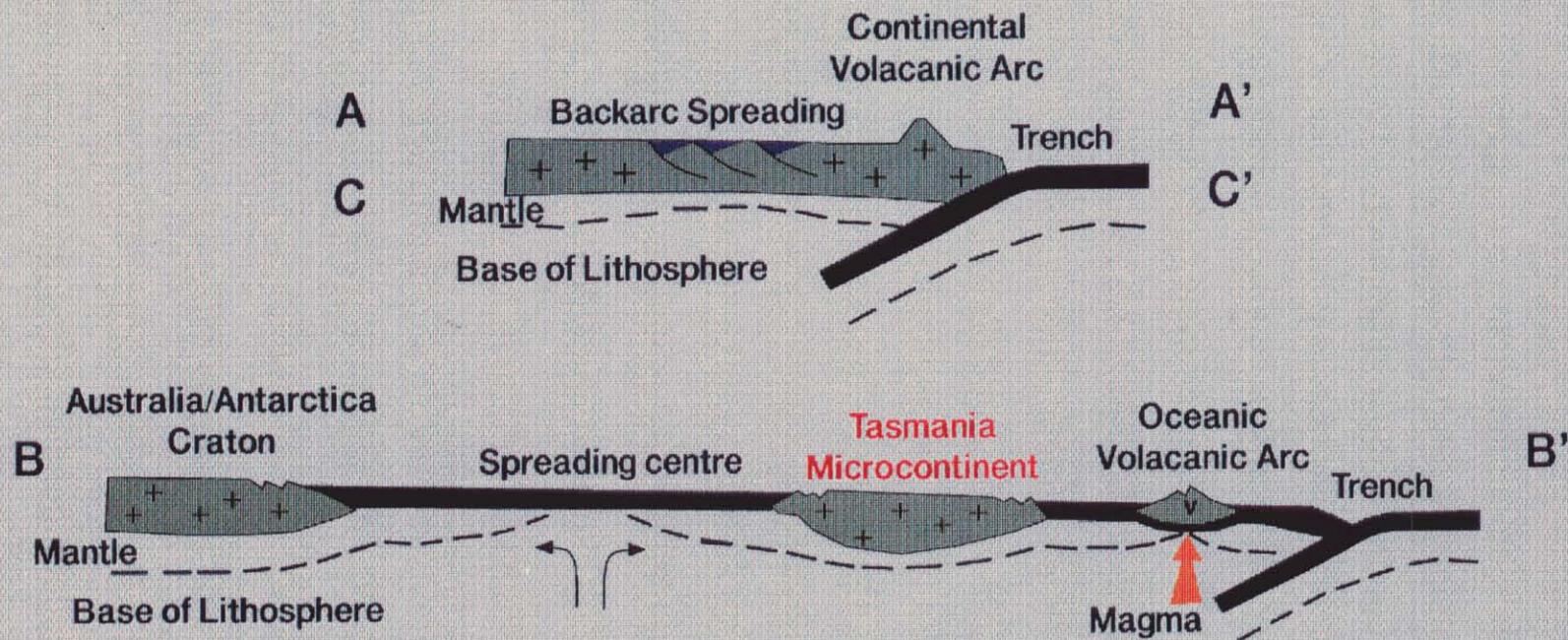
0076



AP9118G-25

369077

TASMANIAN MICROCONTINENT PALEOGEOGRAPHIC HISTORY AND TECTONIC SETTING

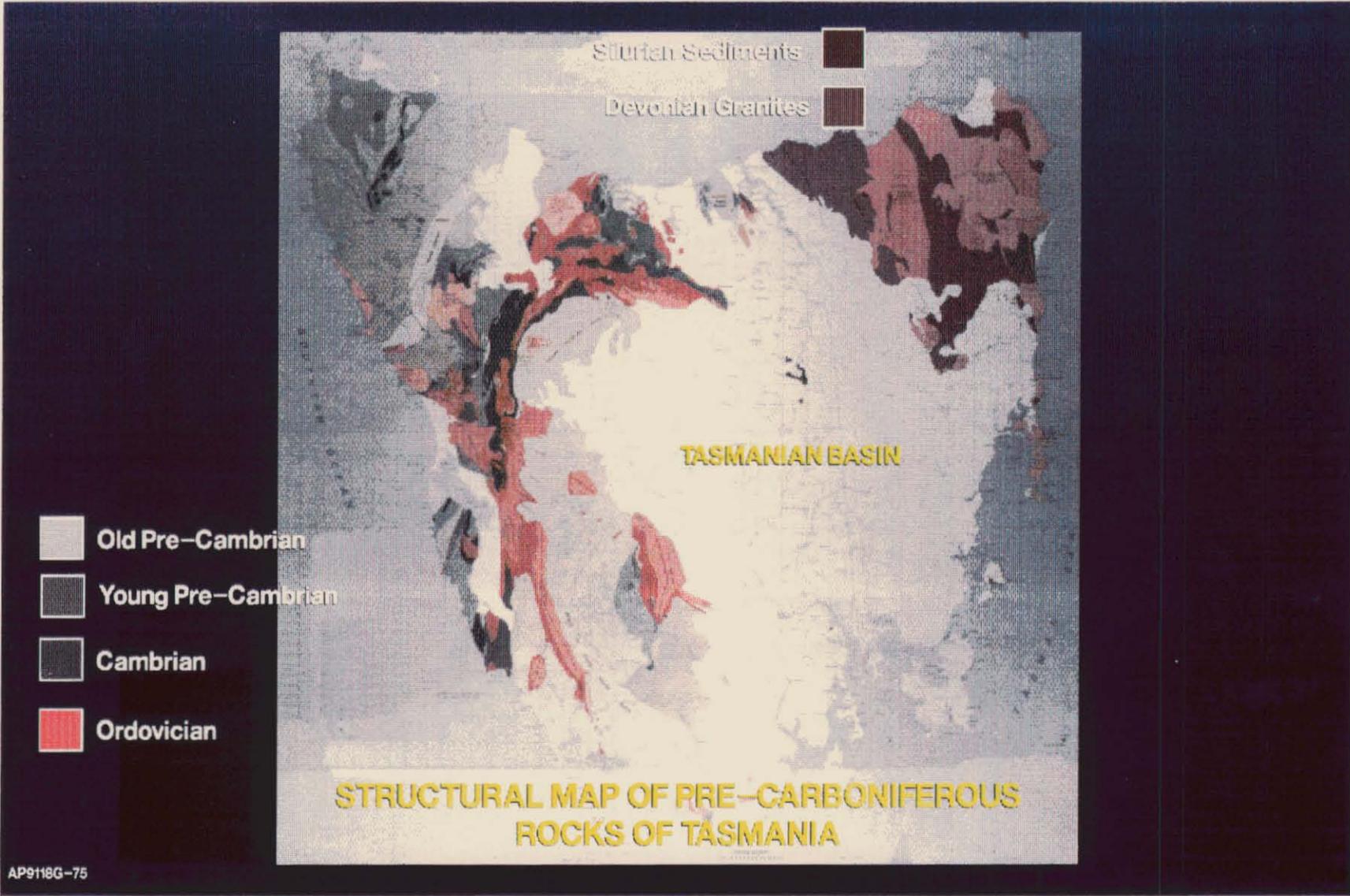


After Bradshaw et al (1985) and Scheibner (1985)

AP9119G-26

57

0078



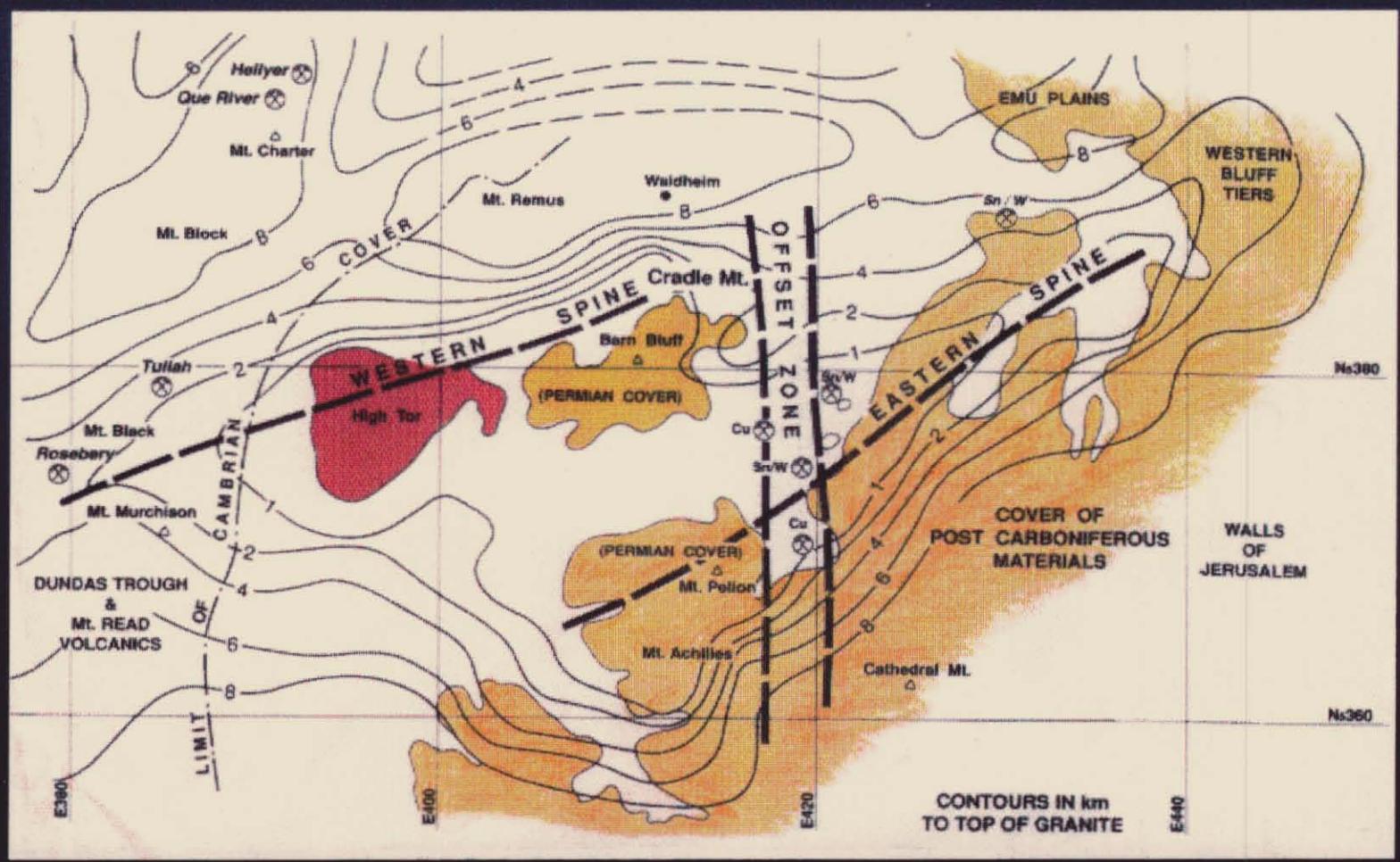
- Old Pre-Cambrian
- Young Pre-Cambrian
- Cambrian
- Ordovician

- Sturtian Sediments
- Devonian Granites

**STRUCTURAL MAP OF PRE-CARBONIFEROUS
ROCKS OF TASMANIA**

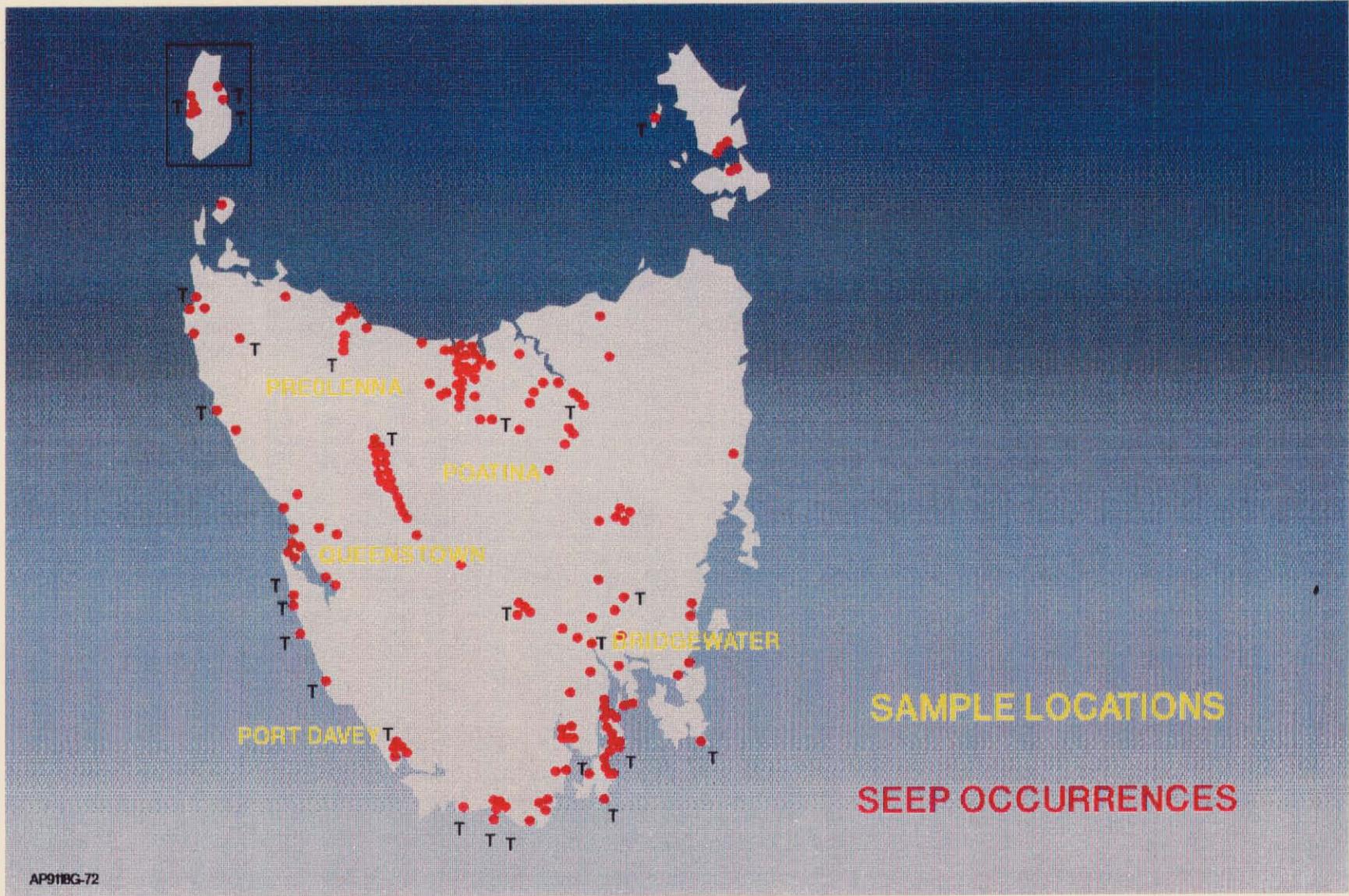
AP9118G-75

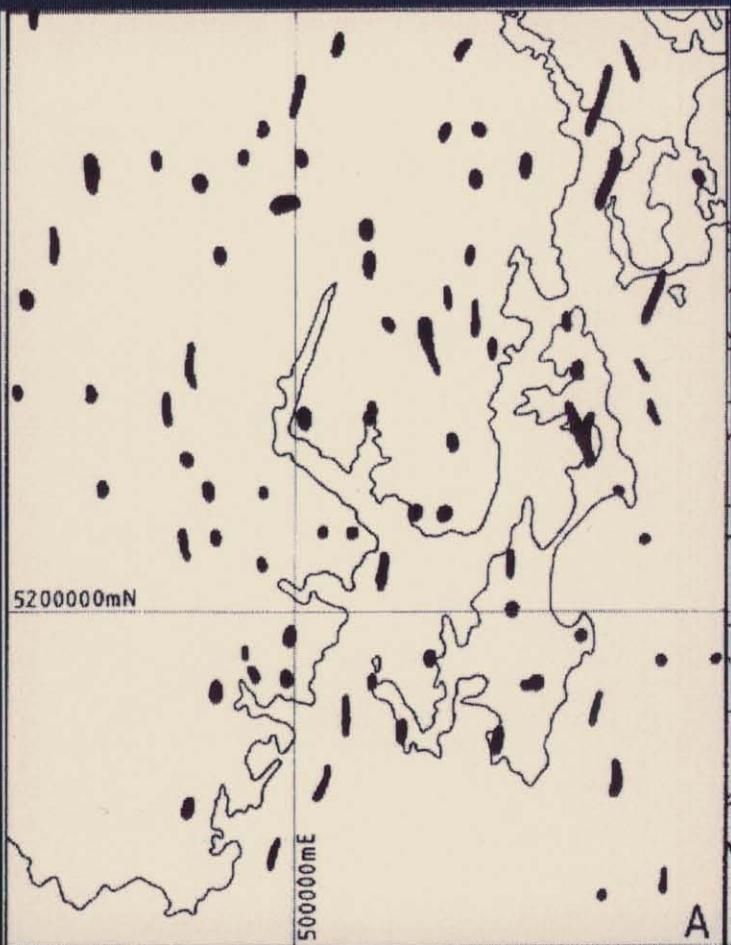
369079



FORM OF TOR GRANITE

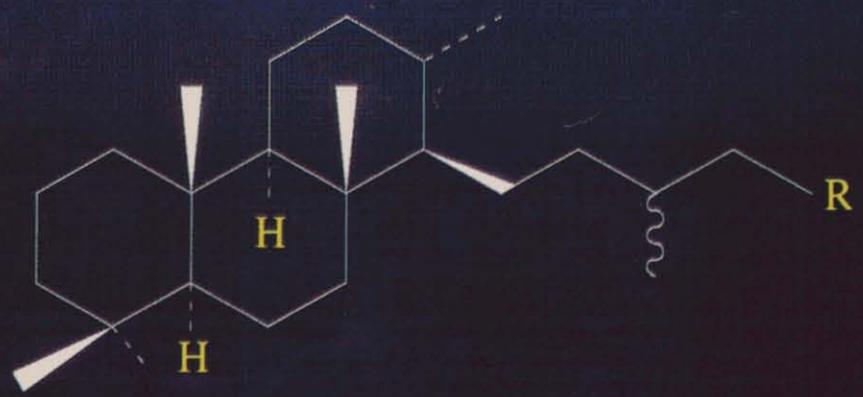
AP9118G-66





DOLERITE FEEDER DISTRIBUTION

AP9118G-60



tricyclic triterpanes

POLYCYCLIC ALKANES USED
TO FINGERPRINT PETROLEUM

AP9118G-23

CONCLUSIONS

1. Many seep occurrences
2. Four mature oils identified
3. Sources, seals and reservoirs defined
4. Structural styles and heating event
suitable for accumulations
5. Seismic fine tuning now needed

AP018G-88

0083

369084