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PETROLEUM EXPLORATION DIVISION

GEOLOGICAL INTERPRETATION OF SEISMIC TIME SECTIONS IN THE GAMBIER EMBAYMENT

by

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PETROLEUM SECTION

1st December, 1967 S.R. 11/5/123

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GEOLOGICAL INTERPRETATION OF SEISMIC TIME SECTIONS IN THE GAMBIER EMBAYMENT

SUMMARY

Time sections from over 1,000 miles of land and marine seismic reflection surveys carried out by Geoseismic (Aust.), Western GeophysicalCo., Namco International, and the South Australian Mines Department, are subdivided into superimposed groups of reflections on the basis of discordance or persistent reflectors. These reflector groups correspond to the major subsurface stratigraphic units determined from the six deeper oil exploration wells. Consequently, the subdivided time sections may be regarded as generalised geological sections from which the broader aspects of the structure and sedimentary distribution in the Gambier Embayment are determined.

The major structural units recognised, are from north to south: Padthaway Ridge, Robe-Penola Trough, The Kalangadoo-Beachport Basement High, and the Mt. Salt Syncline which straddles the present coast south of Beachport. The Padthaway Ridge, the Kalangadoo-Beachport Basement High, and Penola Trough are the products of differential block faulting during the late Jurassic and early Cretaceous, but the Mt. Salt Syncline appears to be a composite feature which resulted from broad down-warping along a (?) late Lower Cretaceous hingeline to the north, complemented by late Upper Cretaceous uplift to the south. The axis of this syncline appears to intersect the older structures in the offshore area northwest of Beachport but the southern flank although slightly discordant with the present continental margin, is probably associated with the formation of this feature.

INTRODUCTION

The present study was undertaken as part of an overall geological investigation of the Gambier Embayment which forms the westernmost part of the Otway Basin.

Seismic data is of particular importance in the Gambier Embayment as outcrops of pre-Oligocene strata are rare and the only information available on the structure and distribution of the older sedimentary units is derived from the deeper oil wells and seismic surveys. Extensive regional seismic surveys have been carried out by the South Australian Mines Department since 1960. These surveys exceed 300 line-miles of continuous profiling and form a network which covers most of the northern half of the basin, providing a good basis for structural studies.

Furtherm seismic reflection work carried out by Geoseismic (Aust.) for Beach Petroleum N.L. and The General Exploration Co. of Australia extends the coverage to the southern boundary of the Hundred of Mayurra, and fills in a gap in the coverage about Penola. In 1964 and 1965, Namco carried out surveys for Alliance Oil Development to supplement the low density coverage between Penola and Mt. Gambier, and to investigate a positive gravity feature southwest of Lucindale. At about the same time, Seismograph Services Ltd. on behalf of the Bureau of Mineral Resources carried out an experimental vibroseis survey in the Mt. Gambier area to determine the usefulness of this new technique in an area where conventional seismic surveys yield little data. Western Geophysical Co. of America, under contract to Haematite Explorations Pty. Ltd. carried out 657 miles of offshore seismic surveys in 1963, that cover a strip up to 25 miles wide along the entire length of the coast, but interpretation of the records except locally, is difficult due to the number of confusing multiple reflections. Early in 1965, an additional 572 miles of marine seismic surveys using C.D.P. shooting procedures were carried out for Haematite Explorations Pty. Ltd. to fill-in and complement the previous survey. The records from this survey are of good quality and permit a fuller analyses of the off-shore structural and sedimentary relationships.

In addition to the seismic reflection surveys, the Mines Department, and Namco International on behalf of Alliance Oil Development have carried out seismic refraction surveys that give data on depths to basement in the Robe, Lucindale, and Naracoorte-Penola-Mt. Gambier areas.

METHOD OF INTERPRETATION

Before interpreting the structure and sedimentary distribution in the basin it is necessary to subdivide each seismic time section prepared from these surveys, into superimposed groups of reflections that can be related to the sedimentary units established from the oil exploration wells.

However, before attempting to interpret the seismic sections, the stratigraphic succession has to be examined in order to predict horizons which should either provide good reflections by virtue of their lithology or as in the case of an unconformity, form the boundary between discordant reflectinns.

The main stratigraphic units established in the basin are given in Table. 1.

TABLE I

Miocene	Glenelg Group	Gambier Limestone
Oligocene	Glenelg Group	Compton Conglom.
Eocene	Lacepede Formation	
Eocene	Knight Group	Dartmoor Formation
Paleocene	Knight Group	Bahgallah Formation
Upper Cretaceous	SHERBROOK GP.	Paaratte Formation
	SHERBROOK GP.	Belfast Mudstone Member
Lower Cretaceous	Otway Group	

Briefly, the main characteristics of the units are as follows:-

Otway Group - ?Upper Jurassic to Lower Cretaceous - may be subdivided into informal upper and lower units on the basis of the inferred unconformity at 4,200 feet in Penola No. 1 Well (Ludbrook 1961). The lithology of the sediments above and below the unconformity are similar, consisting of grey to green mudstone, siltstone, and lithic and feldspathic greywacke.

Paaratte Formation - Upper Cretaceous - Includes the Belfast Mudstone Member Equivalent which together with the remainder of the Paaratte Formation is unconformable on the Otway Group in the onshore area at least. Consists of marine mudstone and paralic silt and fine to coarse sands. The Paaratte Formation may range in age into the Paleocene. In this report the informal term Upper Cretaceous is used for the whole sequence between the top of the Otway Group and the base of the Bahgallah Formation.

Bahgallah Formation - Middle Paleocene. Unconformable on the Upper Cretaceous sediments in marginal areas of the basin and consists of marine limonitic, oolitic and glauconitic grits, sands and clays.

Dartmoor Formation - Middle Paleocene. Gradational with the Bahgallah Formation. Marine, paralic, and non-marine micaceous and carbonaceous sands, silts and clays.

Lacepede Formation - Marine glauconitic limestone, marl and sand.

Gambier Limestone - marine limestone and marl. Disconformable on the Lacepede Formation.

The Bahgallah Formation and the Eocene sediments are generally much too thin to be resolved by seismic reflection methods and are not considered further. Because of the lack of reflections above, 1,000 feet, the Gambier Limestone is not resolved either, so the only sedimentary units that need to be considered are the upper and lower units of the Otway Group, the undifferentiated Upper Cretaceous, and the undifferentiated Lower Tertiary sediments. The undifferentiated Lower Tertiary sediments include all the strata between the unconformity at the base of the Bahgallah Formation and the base of the Glenelg Group. In the off-shore areas where subsurface information on the base of the Glenelg Group is not available, the Lower Tertiary unit includes all post Paaratte Formation sediments.

Fortunately each of the major units is separated from the preceding unit by a disconformity or an unconformity, which can be recognised in the seismic sections, either as a persistent reflector, or as an horizon between discordant reflections.

Each of the several unconformities in the seismic sections can then be traced along the section to one of the deeper wells where they correlate with sedimentary breaks established by palaeontological and lithological means.

Initiallly, time sections prepared by the geophysical section of the Geological Survey, from surveys carried out by that section, were interpreted and integrated with time sections prepared from surveys carried out for the several oil prospecting companies. Overall reflection quality in these sections is poor to fair making it impossible to follow the generally discontinuous reflections over any great distance by time-ties or even character and interval correlation. However, some reflecting horizons are traced for considerable distances by projection of dips across areas lacking reasonable reflections, and across gaps in the coverage.

Interpretation began with the supposition that one of these persistent reflecting horizons which shelves steeply onto basement near Reedy Creek on The Connurra-Kingston Line (plate 3), represents the base of the Otway Group - upper unit. Because of its persistence, the reflection must represent a marked regional sedimentary boundary or more probably, an unconformity. In the off-shore seismic sections a persistent reflection equivalent to the reflector on the CK line is particularly well developed and markedly discordant with the lower reflections; confirming that it represents a marked unconformity within the Otway Group. On-shore unconformity is indicated not only by the discordance of the sparse underlying reflectors, but by wedge out and faulting of the whole sedimentary section below the reflector against basement at the structural boundary of the basin, whereas the overlying strata are relatively unaffected (plate 3). Further confirmation of the presence of an unconformity at this horizon is given at the intersection of the CK and RN lines where the reflector on the CK line corresponds to the boundary between essentially parallel reflectors and converging reflectors or wedgeouts on the RN line (plate 4). This boundary between characteristic reflector groups can be traced along the RN line to the vicinity of the Robe Bore where it is at a depth of 4,500 feet. This represents the approximate depth of the horizon equivalent to the unconformity in Penola No. 1 Well, as predicted from the comparison of the vertical distribution of the micro-floral assemblages (Dettman, 1963).

The characteristic wedgeouts on the RN survey line are also present in other sections that cross the northernmost part of the basin and provide a useful basis for correlation of the base of the Otway Group upper unit.

The only recognisable boundary below the Otway Group -upper unit is at the contact between the Otway Group and basement This contact is mostly below the maximum depth of good reflections and is not defined except in the immediate vicinity of the fault or hingeline bounding the Padthaway Ridge. However, the top of basement has been mapped at the base of recognisable reflections over large areas off-shore by Haematite Explorations (1965).

Near the Padthaway Ridge, the basement boundary plunges steeply south, reaching 10,000 feet within 10-15 miles, according to the refraction surveys carried out north of Robe and Penola. Off-shore aeromagnetic and seismic surveys support this configuration.

The second boundary consists of an unconformity above the Otway Group which corresponds to the base of the Lower

Tertiary sediments. This unconformity is especially obvious on the Struan-Beachport survey line (plate 3), where the Tertiary strata appear to truncate the Lower Cretaceous beds. Unfortunately the almost complete absence of shallow reflections on the RN line southwest of the fault bounding the Padthaway Ridge, and on the CK line north of Robe, prevents accurate determination of the lower boundary of the Lower Tertiary sequence in these areas. In the seismic sections of the northern offshore area, the boundary between the Lower Tertiary sequence and the Lower Cretaceous dediments has been mapped over a wide area on the basis of distinctive reflection characteristics and local unconformity. On shore and south of Robe, a persistent reflector is traced to S.E.O.S. Beachport No. 1 and B.P.N.L. Geltwood Beach No. 1 where it corresponds to the level of the lower boundary of the Lower Tertiary sediments. This reflector has a wide distribution in the central part of the basin and is only lost where the lower members of the Lower Tertiary sediments lens out against the marginal areas of the basin. It is therefore possible that this reflection represents a reflector in the Paleocene-Bahgallah Formation or on unconformity between the Lower Tertiary and the Upper Cretaceous sediments, as distinct from the Lower Tertiary-Lower Cretaceous unconformity mentioned above. In the off-shore seismic sections south of Beachport the boundary between the Lower Tertiary and the upper Cretaceous sediments is well marked by either discordant reflections or a prominent reflector.

The reflector at the base of the Tertiary in the southern part of the Gambier Embayment also represents the upper boundary of the Upper Cretaceous sediments, so the only major sedimentary boundary left unresolved is the base of the Upper Cretaceous.

Time sections prepared by Geoseismic (Aust.) (~~Geosurvey~~, 1962) from surveys in the Hundred of Mayurra show a persistent reflector that corresponds approximately to the level of the base of the Upper Cretaceous in Geltwood Beach No. 1 (plate 3). This reflector corresponds also to a disconformity on the adjacent Mines Department time sections (plate 4) which can be traced some distance to the north and east where it merges with the basal Tertiary reflector. This unconformity is also apparent as an interval between disconformable reflections on the Namco B line (plate 5) and on the Penola-Malla section (plate 5). In the latter section the interval between the disconformable reflections reaches 1,000ft., which allows considerable error in placing the exact depth of the unconformity. The base of the Upper Cretaceous sequence is not delineated in the off-shore seismic sections, apart from some slight discordance of the reflectors in line SS22 (plate 12).

It is apparent from the above account that there are considerable gaps in the record, especially below 4-5,000 feet, where an almost complete absence of information in the on-shore seismic sections makes interpretation impossible. However, there is reasonably good control between depths of 1,000 and 4,000 feet provided by some persistent reflectors which tie in with the stratigraphic subdivisions on the oil exploration wells. In the northernmost part of the basin and in the off-shore areas, the boundaries are delineated by discordant reflections which are either marked by the persistent reflectors or correspond to persistent reflectors in adjacent areas where the discordance is absent or less pronounced.

TABLE II

Area	Boundary				
	Tertiary/ Upper Cretaceous	Tertiary Otway Gp.	Upper Cretaceous Otway Group	Otway Gp. Upper unit Otway GP-Lower Unit	Otway Gp. Basement
Basin Margin	Not represented	commonly marked by a strong persistent reflector which represents the boundary between disconformable reflections	Not represented	commonly marked by a strong persistent reflector which represents the boundary between disconformable reflections.,	Basement re flections are usually much steeper and more linear tha reflection from the Otway Gp.
Deep basin Onshore	Marked by slight angular unconformity	As above	Reflections from upper Cretaceous abut and pinch out against Otway Gp.	As above, Probably not represented south of the Beachport Kalangadoo High	Too deep to be resolve by the reflection seismic method used.
Deep basin offshore	Marked either by a strong persistent reflector or an angular unconformity	Not well delineated but locally represented by slight angular unconformity	Apparently conformable reflections with no change of character	Marked by a strong persistent reflector which represents an unconformity - also a marked difference in character of the reflections on either side of this boundary.	

TABLE II Seismic characteristics of the main stratigraphic boundaries.

Recognition of the major sedimentary units in the time sections, assists interpretation of the overall structure and sedimentary distribution within the basin. Nevertheless, the smaller sedimentary units that are important for a complete understanding of the geology of the basin are not resolved. Unless these smaller units can be related to the character of reflections from the interval which they occupy, it seems probable that information on their distribution will continue to be derived solely from the deeper oil exploration wells.

INTERPRETATION OF THE INDIVIDUAL TIME SECTIONS

Having established a basis for the subdivision of the time sections, it is possible to attempt a more detailed interpretation of sedimentation in the basins by studying the distribution and structure of the individual stratigraphic units. In order to do this, each of the time sections, must be interpreted and described. Finally, correlation of the major structures and trends between the survey lines should provide a basis for the required evaluation.

The time sections that will be described are as follows:-

Struan to Beachport
Robe to Naracoorte
Geltwood Beach to Kingston
Millicent to Penola
Penola to Malla
Namco B line
Namco A and C lines in the Lucindale area
Haematite Explorations survey lines
- SA12
- SS29
- SA10
- SA2 - SS2
- SS22, 24, 25, 26, 27

Reduce to inches

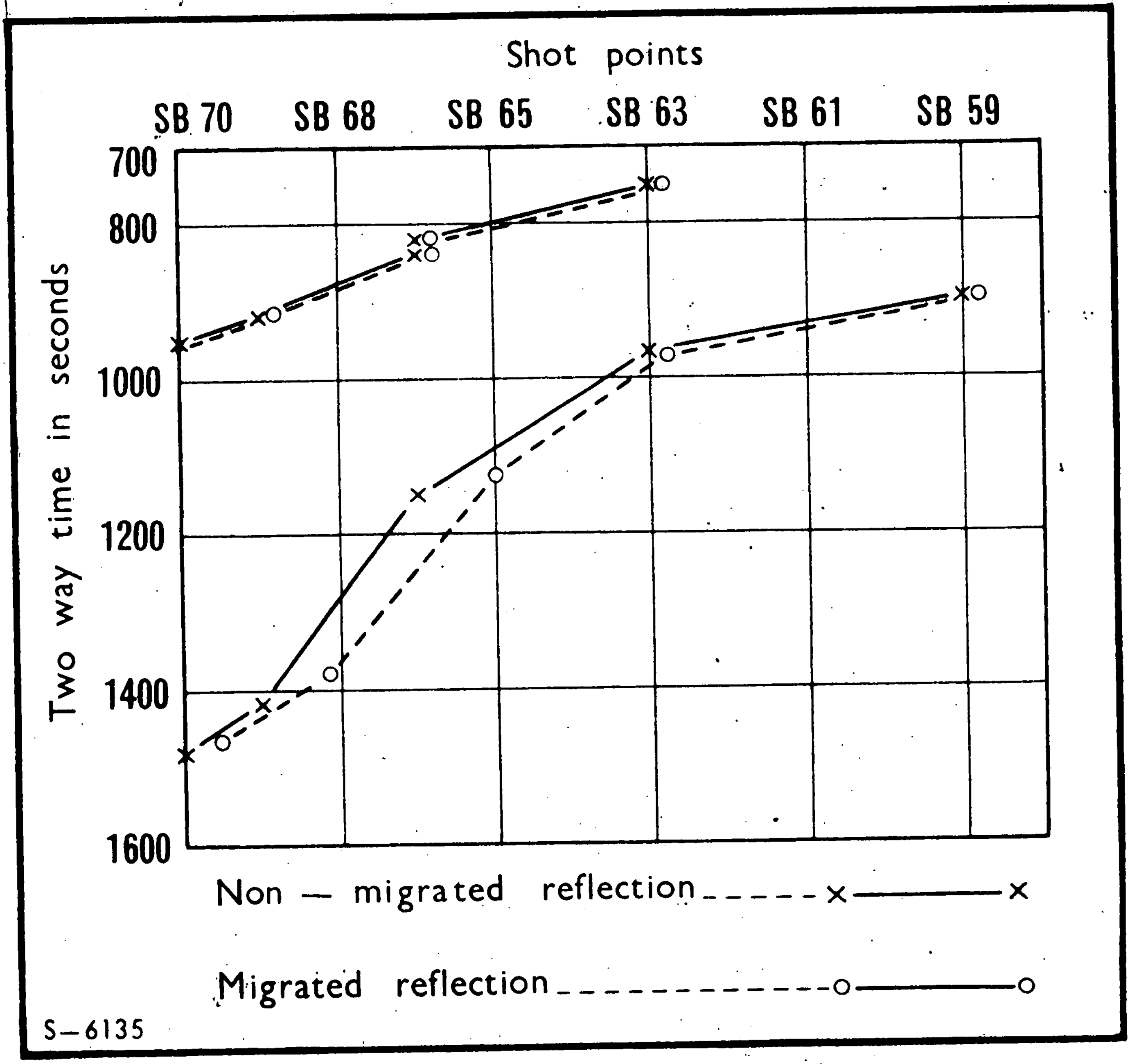

FIG. PLOT SHOWING DIFFERENCE BETWEEN MIGRATED AND NON-MIGRATED REFLECTIONS

Some of the above are composite sections of different but contiguous surveys.

The following sections have been interpreted and are included in the figures at the end of the report but are not described in the text.

S.A. Mines Department A, B and C lines
Kangaroo Inn to Nora Creina Bay
Hundred of Spence
SA3 -SS3
SA13
SA14
SS18
SS19
SS20

All of these sections are non-migrated, but a check plot (figure 1) indicates that the corrections, even in zones of relatively steep dips, are not very great. In addition, the migrated section tends to emphasize these structures exhibited on the non-migrated section

<u>Struan-Beachport Seismic Time Section</u> (plate 3)

This survey line is described first because it gives the best section across the onshore part of the Gambier Embayment.

The line zig-zags from N.E. to S.W., at an angle of about 45° to the regional strike of the sediment, but even so gives a good cross-section through the basin, from the shallow basement area near Struan, to the deep sedimentary area near Beachport. In this section discordant reflectors between shot-points 100 and 50 mark the boundary between the upper and lower units of the Otway Group. From the shot-point 50, the boundary is extrapolated to the northeast along the reflector corresponding to the top of the wedge-outs.

The only other recognisable boundary is that between the Otway Group and the Lower Tertiary. Between shot points 85 and 10 and also between 150 and 170 discordant reflections mark this boundary. From shot-point 180 the discordance becomes less marked, but is replaced by a reflection that persists to the Beachport well, where it corresponds to the base of the Lower Tertiary.

Two major structural features are traversed by the line. The first of these consists of a fault at shot-point 8 At this fault the basement boundary, on the basis of seismic refraction surveys (Seedsman, 1964), is displaced about 800 feet down to the southwest. Reflections in the critical area are sparse but there is some indication that the lower unit of the Otway Group is faulted against or abuts in part, the basement high created by the fault. There is relatively little displacement of the upper part of the Otway Group - lower unit and apparently none at all of the Otway Group - upper unit or Lower Tertiary sequence. However, the fault is associated with a marked increase in the the basinward dip of both the upper and lower units of the Otway Group. The Lower Tertiary sequence on the other hand, does not exhibit any change of dip across the fault.

The second feature again consists essentially of a basement fault with considerable down-throuw to the south adjacent to SP49. Large deltaic type wedge-outs in the lower unit of the Otway Group are directly associated with this structure. Thin, roughly parallel and gently dipping top-sets grade at the fault into thick wedging foresets which plunge up to 4,000 geet in under five miles; representing an average dip of 11°. Each successive hingleine between topset and foreset is displaced further basinward. Wedge-outs of this type are not developed in the overlying upper unit of the Otway Group which does not appear to be displaced by the fault. However, at this point progressive northward truncation of the upper unit of the Otway Group is intensified. Similarly, the Lower Tertiary sediments are not displaced by the fault, but the lower members wedge out against or abut the Lower Cretaceous high, formed by the fault.

Between shot-points 70 and 132, the dips throughout the section flatten considerably and the reflections are essentially conformable. The change in attitude of the reflections in this interval may be caused by the parallelism of the survey line to the regional structural trends. At SP132 where the line turnss south, the Lower Tertiary sequence again becomes unconformable on the Otway Group. The Callendale-Lucindale line (plate 5) extending north of SP132 also supports this view, for the upper unit of the Otway Group in this section is unconformable on the Otway Group - lower unit.

Southwest of SP170, the dip of the reflections in the Otway Group - upper unit flattens and again becomes progressively more nearly parallel to those in the overlying Lower Tertiary sequence. However, the two units may be differentiated by means of a well-defined reflection which occurs at the approximate depth of thebase of the Tertiary near the Beachport Well. This reflection represents the Tertiary-Upper Cretaceous boundary and is a reflector either in or at the base of the Lower Tertiary sequence. It occurs in most of the sections in the deeper parts of the basin and appears to be co-extensive with the distribution of the Upper

Cretaceous sediments. For this reason and also in order to conform with the interpretation of the CK section, a thin lens of Upper Cretaceous is inserted, with somewhat arbitrary boundaries, between the Tertiary and Lower Cretaceous formations. Faulting in the vicinity of SP219 represents the eastern boundary of the thicker Upper Cretaceous sediments and has a similar geometrical shape to the structures bounding the landward extension of Upper Cretaceous sediments in the Millicent-Penola and Penola-Malla sections (~~figures 8 and 9~~).

The thickness of the several sedimentary units is directly related to these structural features. In the case of the lower unit of the Otway Group, significant increase in section from 2,300 feet to more than 4,500 feet is associated with the fault at shot-point 49. However, the local gravity high centred several miles northwest of SP49 (~~figure~~ plate 1) may be the main control on sedimentary thickness. The upper unit of the Otway Group also thins to the north across this structure, but in this case the decrease in section is due to post-depositional truncation. Further south the Otway Group-upper unit apparently thickens steadily and uniformly from about 2,300 feet at shot-point 80 to more than 8,000 feet in Geltwood Beach No. 1.

The lower members of the Lower Tertiary sequence wedge out against the high associated with the fault at shot-point 49, causing a decrease in thickness from 1100 feet to less than 700ft. However, the full effect of the fault at SP8 on sedimentation remains obscure due to the small number of reflections. From the available evidence it appears to be largely a post Otway Group-lower unit structure which faulted a large part of that unit against basement, but has caused relatively little displacement of the younger sediments.

It is apparent from the above observations that the fault at shot-point 49 represents the northern boundary of thick Otway Group-lower unit sedimentation. On the other hand, although the upper unit of the Otway Group wedges out regionally to the north erosional truncation accounts for the main reduction in section north of shot-point 49. Therefore it is probable that the formation once extended far beyond its present northern limit.

Relative uplift of the area north of the fault at shot-point 49 took place after deposition of the upper unit of the Otway Group, forming a high area which was a source for sediment in the basin to the south during the Upper Cretaceous. At a later stage the Lower Tertiary sediments gradually transgressed across the high as the basin subsided. The area of relatively thin Lower Tertiary deposits thus formed is sometimes described as a shelf area (Beachport-Penola shelf of Stach, 1964). This appears to be quite valid if the term, shelf, is used only to designate areas of relatively thin sedimentation, and is restricted in time to the period of formation of these thin sediments.

Robe-Naracoorte Seismic Time Section (plate 4)

This line traverses an area considerably north of the previously described SB line (plate 4) and consequently crosses a much greater part of the "shelf" area. Unfortunately, reflections are very poor throughout the greater part of the section, so the sedimentary boundaries are generally ill-defined.

Between shot-points 270 and 225 a reflector which is discordant on steep, erratic basement type reflections to shot-point 243, and discordantly above Lower Cretaceous strata from shot-point 243 to shot-point 225 marks the lower boundary of the Lower Tertiary sequence. From shot-point 225 the boundary is extrapolated to the only other reliable tie-point at shot-point 13 near the Robe Bore. Additional control on the lower boundary of the Tertiary may be obtained from the short seismic survey line in the Hundred of Spence (plate 6) which approaches the Robe-Naracoorte survey line near SP228.

The boundary between the upper and lower units of the Otway Group is also marked at widely spaced intervals. Between shot-points 210 and 170 discordant reflections represent this boundary as is also the case between shot-points 100 and 40. The Namco "line gives additional control between shot-points 144 and 160 (plate 6). Comparisons with other wells based on palynological evidence (Dettman 1963) suggests that the boundary in the Robe Bore near SP13 should be at approximately 4500 feet, which also represents the depth of the disconformity in the seismic section.

Between shot-points 190 and 270, very steeply dipping discordant reflectors suggest basement. From shot-point 170 the boundary is extrapolated to shot-point 120, about 1 mile south of a refraction survey. The Namco refraction line RG which runs N-S between shot-points 144 and 160, gives additional control.

In spite of the poor record quality it is possible to recognise two major structures similar to the structures described in the SB section. The distribution of reflections about shot-point 210 suggests that the lower unit of the Otway Group is completely faulted-off against basement. If this interpretation is correct, the throw probably exceeds 1000 feet. The upper unit of the Otway Group also appears to be displaced by the fault, but contrary to the equivalent structure at SP8 on the SB line, the steep dips north of the fault become almost horizontal to the south. These horizontal reflections are markedly unconformable on the west-dipping reflections from the Otway Group-lower unit.

Large scale wedge-outs converging on SP100 probably represent a continuation of the structure described at shot-point 49 on the Struan-Beachport survey. The wedges in this area also plunge up to 4,000 feet in 4-5 miles before flattening and are markedly discordant with reflections from the overlying Otway Group-upper unit.

In the vicinity of shot-point 45 there is a basic reversal of dip throughout the section. This synclinal structure, in conjunction with the thickening of the lower part of the sedimentary section at least, suggests that a sediments filled trough is situated between shot-point 100 and the Robe Bore.

Between shot-points 100 and 170 there are no reflections from the upper unit of the Otway Group or Lower Tertiary, but localised groups of reflections from the lower unit of the Otway Group indicate a persistent basinward dip which is probably modified only in the vicinity of the Lucindale Basement High. The attitude of the strata of the Otway Group-upper unit in adjacent areas suggests that they are approximately horizontal in this interval, so considerable truncation and wedging of the Otway Group-lower unit probably takes place between shot-points 100 and 210. The Namco seismic sections support this conclusion indicating that wedge-out of the lower unit of the Otway Group occurs up the flanks of the Lucindale Basement High (plate 6).

Because of the lack of definition of the basement boundary it is not possible to measure thicknesses of the Otway Group-lower unit at a number of intervals along the survey line to check the degree of truncation. However, a refraction survey near shot-point 120 gives a depth to basement of 8,600 feet indicating that the Otway Group-lower unit is 6,000 feet thick at this point.

This thickness reduces to about 2,000 feet between shot-points 144 and 160. Northeast of the Lucindale basement high, the sectian increases again, before wedging out with some truncation and faulting against the Padthaway Ridge at SP210.

The Otway Group-upper unit has a thickness of about 3,000 feet in the Robe Bore and may be somewhat thicker in the axial part of the trough at shot-point 40. East of shot-point 100 the thickness reduces to less than 2,000 feet; a reduction which is probably due to truncation across the flank of the Lucindale Basement High. Between shot-points 100 and 210 the thickness does not vary much, but renewed truncation over the basement high north of the fault at SP210, reduces the section from 2,000 feet to about 300 feet at shot-point 242. The fault at shot-point 242 faulted off the remaining part of the upper unit of the Otway Group, allowing the Lower Tertiary sediments to rest directly on basement to the north.

There are far too few controls on the Lower Tertiary boundaries to analyse the thickness distribution. It is expected however, that the Lower Tertiary sequence thins from about 800 feet at the Robe Bore to less than 500 feet over the shelf area east of shot-point 100.

This "shelf" area is, similarly to the situation along the Struan-Beachport line, a zone over which the top of the Otway Group becomes progressively truncated and the lower part of the Tertiary section is reduced. However, the Otway Group-lower unit thickness of 6000 feet at the western boundary of the "shelf" contrasts to approximately 2800 feet at the equivalent position on the Struan-Beachport line.

Geltwood Beach-Kingston Seismic Time Section (plate 3)

This line represents the combination of several surveys carried out by the South Australian Department of Mines and Geoseismic (Aust.). The Conmurra-Millicent and Conmurra-Kingston surveys were undertaken by the Department of Mines, and the Millicent-Geltwood Beach section represents part of a comprehensive seismic survey of the Hundred of Mayurra by Geoseismic (Aust.), on behalf of Beach Petroleum N.L.

There is generally good control of stratigraphic boundaries, of which three are recognized. The best defined boundary consists of a good reflector between shot-points CK55 and CK163 which separates the upper and lower units of the Otway Group. Below this reflector, the reflections from the Otway Group-lower unit are discordant, especially in the vicinity of the fault at CK152. The reflector also corresponds to the horizon of discordance at the top of the wedge-outs in the Robe-Naracoorte section (plate 4).

The next boundary recognized lies between the Otway Group-upper unit and the Upper Cretaceous sequence, and is marked between Geltwood Beach and Millicent by a reflector corresponding approximately to the level of that stratigraphic boundary in Geltwood Beach No. 1. This reflector also corresponds to a minor disconformity which can be traced from Millicent to shot-point CM10 where it corresponds to a prominent reflector. North of CK15 the boundary is lost, but the overall wedging of the Upper Cretaceous section indicates that it wedges out completely south of shot-point CK50.

A persistent reflector also delineates the boundary between the Upper Cretaceous section and the Lower Tertiary Sequence. This reflector corresponds approximately to the Lower Tertiary-Upper Cretaceous boundary in the Geltwood Beach Well and extends from Geltwood Beach to shot-point CK40 where it ties in with the corresponding boundary traced from Beachport No. 1 to the intersection of the Struan-Beachport and Conmurra-Kingston surveys.

North of shot-point 50 the boundary between the Lower Tertiary and the Otway Group cannot be defined because of the lack of reflections. Consequently the boundary shown represents an extrapolation from shot-point 50 to the position ofS.O.O.C. No. 1 Bore northwest of shot-point 170 (plate 1) where the Lower Tertiary sequence rests on basement at 775 feet.

The basement boundary north of the fault at SP152 is marked by the reflector at the base of the Otway Group-upper unit, with an additional control point at the bore mentioned above. South of the fault, the boundary is drawn above steeply dipping reflections between shot-points CK150 and CK140 and extrapolated to shot-point CK124 where a refraction survey indicates a depth to basement of 9,400 feet.

Generally the reflections throughout the section dip southward from the Padthaway Ridge in sympathy with the basement boundary thus defined. In the vicinity of shot-point 50 some flattening and possible arching is associated with increased dips to the south. Where the survey extends latitudinally between Millicent and Geltwood Beach, the reflections are more or less horizontal.

Of the two major structures described in the Struan-Beachport and Robe-Naracoorte lines, only the near margin fault that limits the northern extent of the Otway Group-lower unit is recognized in the Geltwood Beach-Kingston section. Strongly wedging reflectors in the lower unit of the Otway Group south of the fault, suggest that the unit did not extend very far to the north. The wedge-outs appear to be truncated by the fault and consequently are not completely defined. However, the wedge-outs may be associated with a northward extension of the hingeline established at shot-point 100 on the Robe-Naracoorte survey line. If this is the case, the marginal fault of the Gambier Embayment in this area cuts across a major structural trend controlling sedimentation of the Otway Group-lower unit.

The overlying upper unit of the OtwayGroup appears to be relatively undisturbed by the fault at SP152 and extends several miles to the north before complete truncation beneath an unconformity. Comparison with the same structure on the off-shore line SA12 (plate 7) where more detail is shown in the section, suggests that wedging of the lower members of the Otway Group-upper unit takes place north of the fault.

There are no reflectors from the Lower Tertiary sequence with which to determine whether any displacement of these sediments across the fault takes place.

The only other structure of consequence in the section is situated between shot-points 50 and 55 and is somewhat ill-defined. In this vicinity, faulting of the Otway Group-lower unit is associated with a high of Lower Cretaceous sediments against which the whole of the Upper Cretaceous and the lower part of the Tertiary section wedges out.

Probable truncation of the Otway Group-upper unit over this high reduces its thickness from about 4,000 feet to 3,000 feet at shot-point 90 and to less than 1500 feet near the Padthaway Ridge. Drilling at Geltwood Beach shows that the upper unit of the Otway Group exceeds 8000 feet in thickness so there must be considerable wedging and possibly truncation northward to shot-point CK50.

Information on the thickness of the Otway Group-lower unit is available only north of shot-point 124 where the sequence wedges, with some truncation, from 6000 feet at S.P. 124 to 1200 feet near the fault at S.P. 152.

The Upper Cretaceous sediments are about 1800 feet thick at Geltwood Beach, and as previously stated, wedge out completely against the high at shot-point CK50. A disconformity at least is indicated by the wedging of the lower part of the Lower Tertiary sequence against the Upper Cretaceous sediments, but there are too few reflections to determine whether truncation also contributes to the northward reduction in section.

In spite of the obvious northward wedging, the Lower Tertiary thickness decreased by only 300 feet from 1300 feet to 1000 feet between Geltwood Beach and shot-point 50. North of shot-point 50 the thickness probably increases again as the survey line approaches the axial position of the Robe Trough and decreases to less than 700 feet over the southern part of the Padthaway Ridge.

It is apparent from the above description that the Geltwood Beach to Kingston section does not cross the same shelf area of relatively thin Lower Tertiary sediments overlying truncated Lower Cretaceous sediments, that appears on the Struan-Beachport and Robe-Naracoorte sections. However, another hingeline in the vicinity of shot-point 50 has resulted in uplift that formed a barrier to the Upper Cretaceous transgression and has caused some thinning of the Lower Tertiary sequence. This apparent uplift maybe associated with the small gravity high southeast of Robe, over which the lower unit of the Otway Group wedges on the Namco C line.

Truncation of the upper unit of the Otway Group over this high also, is suggested by the reduced section and steep dips associated with the hinge-line. These features are similar to those described for the "shelf" area to the northeast, so there is some doubt over the unity and character of the shelf.

The hinge-line at shot-point 50 is also closely related to structures controlling Upper Cretaceous sedimentation near Krongart and Wattle Range.

Millicent-Penola Seismic Time Section (plate 4)

This section also represents the combination of several seismic surveys carried out by the South Australian Departmet of Mines and Geoseismic (Aust.) under contract to the General Exploration Company of Australia Limited. The section extends from shot-point 55 on the Conmurra-Millicent line, 4 miles north of Millicent, to a point 7 miles north of Comaum. Penola No. 1 Well is on the line of section near shot-point 62 and the Comaum Coal Bore is less than 2 miles east of shot-point 19/5.

Generally the reflections within the section all dip basinward except for local reversals due to gentle folding. The shallower reflections in most cases dip less steeply than the deeper reflections, providing a basis for subdivision of the section. In this regard the boundary between the upper and lower units of the Otway Group is delineated between shot-points 60 and 78 by discordance between steeply plunging wedges and the non-wedging, less tilted overlying strata. This discordance is near the level of the unconformity at 4200 feet, in the Penola Well. North of shot-point 78, the boundary follows a disconformity which becomes less well defined due to local discordances within the Otway Group reflectors.

The Otway Group - basement boundary is again based on discordant reflectors. In this case, the steeply dipping linear reflectors typical of the basement are readily distinguishable fm the folded and less steep reflectors in the Otway Group. Even so, the basement boundary because of its steep basinward plunge, can be traced for a distance of only 7-8 miles from the margin of the basin.

Thebase of the Lower Tertiary sequence, contrary to the other boundaries, is marked by a reflector which is traced from the Penola Well to the Geltwood Beach-Kingston survey line, where it corresponds to a reflector that extends in that setion to Geltwood Beach No. 1. This reflector generally parallels the underlying reflectors except to the north of shot-point 145 where it appears to truncate the upper members of the Otway Group-upper unit.

South of shot-point MP125 a wedge of Upper Cretaceous sediments, disconformable on the Otway Group-upper unit develops beneath the Lower Tertiary sequence. This disconformity corresponds to the reflector marking the base of the Upper Cretaceous in the Geltwood Beach to Kingston section. Generally the dips of reflections within the Upper Cretaceous are intermediate between the average $\frac{1}{2}^{o}$ in the Lower Tertiary sequence and the average of $1\frac{1}{2}^{o}$ in the upper unit of the Otway Group. Consequently some degree of discordance exists between the Lower Tertiary and the Upper Cretaceous sediments.

The steepest dips in the Millicent-Penola Section are associated with the down-warped area of Upper Cretaceous sedimentation southwest of shot-point 139 and the marginal area of the basin north of Penola. These zones delineate major structures that are recognized in some of the previously described sections.

The steep dips north of Penola are apparently associated with the two major fault systems recognized in the Struan-Beachport and other sections. The northernmost of these two structures is associated with a change from relatively flat to steeply dipping reflections south of shot-point 19/1. Although there is no fault indicated on the section, this hinge-line corresponds to the position of the Kanawinka Fault.

The other hinge-line is developed about 3 miles south of the Kanawinka Fault where the plunge of the basement surface steepens south of shot-point 19/13. Reflectors within the lower unit of the Otway Group wedge strongly against this basement high in much the same manner as at shot-point 49 on the Struan-Beachport section, indicating that the same structure is intersected in each case.

The remaining structure in the section that significantly affected sedimentation is the system of faults between shot-points 123 and 139. Relative movement along the fault is north block down, associated with basinward down-warping of the south block, which, in conjunction with the near reversal of dips across the fault, suggests that arching of the Lower Cretaceous strata is also involved. It is this arching that controlled the northward extension of the Upper Cretaceous sediments.

Thickness distributions of the several sedimentary units are, as previously stated, strongly affected by each of the above structures. In this regard, the Otway Group-lower unit wedges from about 4,000 feet at shot-point 75 to less than 1,000 feet near the hinge-line intersected at shot-point 19/14.

This hinge-line is also associated with a post-Lower Cretaceous high area over which erosional truncation of the upper unit of the Otway Group has taken place. Microfloral correlations (Harris & Cookson, 1965) support this observation and indicate that about 1,600 feet of the upper part of the Otway Group-upper unit in the Penola Bore has been reduced to less than 50 feet in the Comaum Bore. Some wedging is indicated between these bores, but the greater part of this reduction in section must be due to truncation. On a more regional scale the Otway Group-upper unit wedges, with some truncation northeastward of shot-point 145, from more than 8,000 feet near Millicent to 3,200 feet at Penola No. 1 Well.

The Upper Cretaceous sediments also wedge out to the northeast from about 2,000 feet near Millicent to zero at shot-point 130. There are too few reflections from this section to determine the other factors involved, but it is likely that the lower members abut the arched Lower Cretaceous sediments south of shot-point 130 with some limited truncation of the upper members north of shot-point 115.

The Lower Tertiary sequence on the other hand, seems to be little affected by the structure that limited Upper Cretaceous sedimentation. Weak convergence of the reflections indicate regional wedging northeastward from Millicent, but the main thinning occurs over the positive area of Lower Cretaceous sediments associated with the hinge-lines north of Penola. In this zone the thickness decreases from about 1250 feet at Penola township to 750 feet at Penola No. 1 and to 100 feet at Comaum. This occurs in contrast to an overall increase in thickness from about 1,100 feet to 1250 feet between Millicent and Penola.

The main difference in sedimentary distribution along the line of the Millicent-Penola section results from the apparently small displacement along the Kanawinka Fault, which allows transgression of both the Lower Cretaceous units some distance to the north.

Consequently although thinning of the section is associated with the Kanawinka Fault, it is not the boundary of the Gambier Embayment in this area.

Penola-Malla Seismic Time Section (plate 5)

The Penola-Malla Survey was carried out by Geoseismic (Aust.) for the GeneralExploration Company of Australia and extends from Penola to within 18 miles of Mount Salt No. 1 Well. The section lies wholly within the basin and does not intersect the marginal structures observed in the previously described sections.

Within this section the main structural feature consists of a broad asymmetric anticlinal ridge centred on Krongart. The asymmetry is associated with faulting which has produced downwarping of the southern limb. This structure has the same form as the arching about shot-point MP 139 on the Millicent-Penola survey line (plate 4) and as they each form the northern boundary of Upper Cretaceous sediments, it is considered that they are part of the same structure.

The arching about Krongart has affected sedimentary distribution and produced disconformities between the sediment wedges which can be used to delineate stratigraphic boundaries. However, a persistent reflection which extends right across the section and corresponds to the reflector at the approximate level of the Lower Tertiary-Otway Group boundary in Penola No. 1 is also useful for correlation. This reflector appears to be about 100 feet below the level of the base of the Lower Tertiary sequence in Penola No. 1 Well so it probably represents an event in the uppermost part of the Otway Group.

South of Krongart a sedimentary wedge referable to the Upper Cretaceous develops above the reflection near the top of the Otway Group. In this part of the section the lowest reflector in the Upper Cretaceous sequence is unconformable on the reflector near the top of the Otway Group. However, as a considerable gap exists between the two reflectors it is not clear whether the lower part of the Upper Cretaceous sequence wedges out against the Otway Group or whether a sequence in the upper part of the Otway Group is truncated by the Upper Cretaceous. However, information from the Kalangadoo Well at SP88 indicates that the lowest reflector in the Upper Cretaceous corresponds approximately to the base of that sequence. There are too few reflections within the Upper Cretaceous sequence to determine the sedimentary trends accurately, but some wedge out to the north is apparent in addition to truncation of the upper members north of Kalangadoo. This truncation represents the Lower Tertiary-Upper Cretaceous boundary and is traced south of Kalangadoo along reflections immediately above the unconformity.

It is apparent from the above observations that the arching centred on Krongart has a marked effect on the thickness distribution of the Upper Cretaceous and Lower Tertiary sediments. The Upper Cretaceous section wedges out with some truncation from about 2500 feet at Malla to 0 feet immediately north of Krongart. Over the same interval, the Lower Tertiary sequence wedges from 2,600 feet to 1,100 feet, increasing in thickness again to 1,400 feet on the north limb of the arch.

Although absolute thicknesses of the upper unit of the Otway Group cannot be determined, it is apparent from the parallelism of the reflections that little or no lensing takes place over the arch. However, a small sequence near the top of the group appears to be truncated. Consequently this structure must have developed in the interval between the cessation of Lower Cretaceous sedimentation and the beginning of the Upper Cretaceous transgression.

Some movement along the faults associated with the arch must have occurred since the Middle Tertiary, as displacement of the Gambier Limestone in this area is suggested from bore information.

Namco B Line (plate 5)

This survey was carried out by Namco for Alliance Oil Development N.L. (Namco International Inc. 1964), and fills in a large gap in the seismic coverage between the Penola-Malla line and the Hundred of Mayurra surveys.

The most notable feature of this survey line is the northward wedging of the reflections throughout the section. However, a marked unconformity north of SP95 forms a good basis for subdivision. This unconformity represents the boundary between the Lower Tertiary and the Otway Group, and can be traced southwards to SP24. South from SP95 a thick wedge of sediments corresponding to the Upper Cretaceous section at the intersection with the Millicent-Penola survey line, develops between the Lower Tertiary and the Otway Group.

The Upper Cretaceous-Lower Tertiary boundary appears to be conformable and is delineated only be a reflector between SPs 50 and 100. This reflector is immediately above the unconformity at SP100 and corresponds to the reflector representing the top of the Upper Cretaceous at the intersection with the Millicent-Penola survey line.

Another unconformity is indicated between SPs 60 and 70 where steeply inclined and strongly wedging reflections are present beneath the upper unit of the Otway Group at a depth of 7,600 feet. These reflections are possibly derived from the lower unit of the Otway Group.

Steep dips within the upper unit of the Otway Group between shot-points 60 and 100 probably represent the south limb of the same ridge or arch which limits Upper Cretaceous sedimentation along the Millicent-Penola and Penola-Malla survey lines. The 1,600 feet of Upper Cretaceous strata at shot-point 50 wedge out completely against this ridge, and the Lower Tertiary as a whole wedges from 1,800 feet at SP60 to 1,100 feet at SP100. Reflections within the upper unit of the OtwayGroup also wedge to the north, but it is not clear whether this is localised over the ridge or represents part of a regional trend.

Namco International Seismic Surveys in the Lucindale Area

(plates 5 and 6)

During the first half of 1965, Namco International carrie out 83 miles of seismic reflection traverses in the Lucindale area for Alliance Oil Development Aust. N.L. These traverses were located to evaluate a localised gravity high centred eight miles southwest of Lucindale and herein referred to as the Lucindale Basement High. In addition to the seismic reflection surveys a north-south seismic refraction traverse is located across the centre of the gravity high.

The refraction survey proved that the gravity high reflects a basement high with basement depths ranging from a minimum of 3,100 feet below sea level on the high, to 5,800 feet north of the high, and greater than 10,000 feet south of the high.

The reflection surveys indicate that the Lower Cretaceous sediments are not only draped over the high, but the lower part of the sequence wedges out up the flanks of the high. Where the Namco surveys intersect the S.A. Mines Department survey lines, it is found that the boundary between the wedging and non wedging sequences corresponds to the unconformity between the upper and lower units of the Otway Group. This horizon as contoured in the Lucindale area by Namco fits quite well the regional contours in the reflection time contour map, on the base of the upper unit of the Otway Group (Taylor, 1964).

The lower unit of the Otway Group beneath this unconformity follows the previously defined trend, by wedging out almost completely over the Lucindale Basement High as at Beachport and Kalangadoo. Significant wedging of the section toward the western end of line C suggests that the lower unit of the Otway Group also wedges out over the gravity high centred on Lake Hawden South.

The large scale wedge-outs in line A along the southern flank of the Lucindale Basement High, correspond to the northern boundary of wedge-outs in the lower Otway Group as previously defined (plate 16). However, wedging of the remainder of the sequence about the high appears to displace this structural line northwards about the flanks of the high (plate 16). In this regard, although the wedging out of the lower unit of the OtwayGroup over several basement highs complicates the structural configuration, the general concept that the Robe-Penola Trough is bounded by zones of major wedge-outs in the OtwayGroup-lower unit, remains valid.

The other major unconformity in the stratigraphic sequence in the Lucindale area (between the Otway Group and the Lower Tertiary) is poorly defined due to the paucity of shallow reflections. However, a disconformable shallow reflection along line C(plate 6) and along the southern part of line A (plate 6) probably represents a reflection at the base of the Lower Tertiary sequence. One major divergence from previously held concepts is the absence of any indication of faulting across the line of the Lucindale Fault. In consequence it maybe best to discard the poorly defined, hypothetical concept of a single major fault bounding the GambierEmbayment.

Haematite Explorations Line SA12
(plate 7)

The survey is generally parallel to the coast and is of particular interest as it extends from the shallow basement area near Cape Jaffa, across an extension of the Robe Gravity Trough to the vicinity of Beachport. Reasonably persistent reflections and the lack of complex faulting facilitate subdivision of the section.

The main feature of this section is a fault with considerable downthrow to the south, which is intersected at SP97 (Hopkins, B.M. and Baker, M.C., 1963). This fault forms the boundary between shallow and deep basement areas and therefore represents the structural boundary of the Otway Basin. Information from the other off-shore geophysical surveys indicates that the fault extends east-west, in which case it would intersect the coast about five miles south of Cape Jaffa. Consequently it is suggested that the off-shore fault or hinge-line swings north to connect with the shallow basement boundary near shot-point 150 on the Conmurra-Kingston survey line.

The reflections in the vicinity of this fault may be subdivided on the same basis as the reflections near the fault at SP152 in the Conmurra-Kingston section. In both instances an upper group of reflections transgresses down-faulted reflecting groups onto basement without major displacement. The upper group of reflections is assigned to the upper unit of the Otway Group and is unconformable on the lower group of reflections which corresponds to the Otway Group-lower unit. Reflections from the lower unit of the OtwayGroup indicate that the overall dip between the fault and shot-point 48 is to the north, in contrast to the reflections from the upper unit of the Otway Group which are essentially horizontal. It is estimated that the truncation over this interval has removed about 5000 feet of section from the lower unit.

Near SP48 the reflector marking the boundary between the upper and lower units of the Otway Group becomes discontinuous and deepens considerably towards SP28. South of SP28 there are no recognisable reflections below the prominent reflector so it probably represents the top of basement in this area. The relationship to basement of the reflector or series of reflectors between SP48 and SP28 is obscure, but the remainder of the sedimentary sequence beneath the upper unit of the Otway Group must be truncated completely, somewhere in this interval.

A similar structure appears in most of the seismic sections that cross the Robe Trough so it is considered that the structure at SP48 represents part of a regional hingeline or fault. South of this structure the remaining strata of the Otway Group-lower unit are completely truncated and the upper unit of the Otway Group thickens and dips southward over the offshore extension of the Beachport high. This structure is geometrically similar to the Krongart structure from which the upper unit of the Otway Group dips southward without modification over the Kalangadoo High.

The Lower Tertiary sediments are not affected by the above structures as the base of the sequence has very little relief. Near SP105 the base of the Lower Tertiary rests on basement at 1000 feet and extends southwards, mostly without significant angular unconformity on the Otway Group at depths between 1200 and 1600 feet. Near Beachport the base of the Lower Tertiary deepens to about 1800 feet.

Thickness variations in the Lower Tertiary cannot be estimated because the base of the Glenelg Group is not delineated. However, the upper and lower boundaries of the upper unit of the Otway Group are delineated and show that this sequence thickens rapidly south of the Padthaway Ridge to 4000 feet. This thickness remains constant over the Robe Trough, but increases to 5000 feet south of the structure at SP48, before thinning to about 3600 feet opposite the Beachport Basement High. The base of the lower unit of the Otway Group is not positively established but the line drawn at the base of the more definite reflections, indicates that the sequence maybe at least 7000 feet thick.

Haematite Explorations Line SS29
(plate 8)

Line SS29 is 10 miles seaward from and roughly parallel to Line SA12. Similar structural relationships between the upper and lower parts of the Otway Group are displayed on both sections, with strong reflectors marking the unconformity in each case. The reflections in the upper unit of the Otway Group above the unconformity have a small but consistent south-dip, similarly to Line SA12. However, reflections from the lower unit of the Otway Group progressively develop beneath the unconformity southward from SP7 and the sequence thickens rapidly to about 5000 feet at SP29 without any apparent faulting.

South of shot-point 30, conformable reflections extend down to 3.5 seconds. These deep reflections are considered by Haematite Explorations (1965) to belong to a wedge of Jurassic sediments faulted against basement at SP30. This sedimentary wedge appears to be conformable with, and probbly represents part of the lower unit of the Otway Group.

At SP31 the dips in the lower unit of the Otway Group are reversed and the sequence is progressively truncated to the south. Between shot-points 31 and 100, the reflector marking the unconformity remains well-defined and nearly horizontal. South of SP100, however, the reflector becomes less continuous and dips relatively steeply to the south. Similar behaviour of this reflector appears on lines SA12, SS19, SS18, SS3, and less clearly on SS2. The line joining this feature on each of the above lines is a curve of large radius, suggesting a single regional structure (plate 16). Contours of the reflector on either side of this line or structure are disconformable (plate 16), suggesting either different reflectors or a different structural background.

An interesting point is that if the reflector on top of the downfaulted sequence at SP30 is ghosted southward, it is truncated by the unconformity at about SP100, where the reflector marking the unconformity changes character. In addition, this reflector can be ghosted to line 12 where it corresponds to the base of the positive reflections which are completely truncated beneath the unconformity at SP48.

The thickness of the upper unit of the OtwayGroup is also affected by the structure at SP100. Between shot-points 1 and 100, the upper unit of the Otway Group thickens gradually from about 1000 feet to 4000 feet. However, between shot-points 100 and 127 the thickness increases from 4000 feet to 7000 feet. Lack of good reflections beneath the upper unit of the Otway Group south of SP120 suggests that it rests on basement over this interval. Consequently the structures and sedimentary relationships in the vicinity of SP100 are identical to, and probably continuous with the structure at SP48 on line SA12.

GENERAL COMMENTS ON SELECTED OFF-SHORE TIME SECTIONS

Haematite Explorations Line SA10 (plate 9)

The features described in the SS29 section are reproduced in the SA10 section, but are not as well-defined due to the poor record quality. The steeply dipping reflections near shot-point 250 represent the northern margin of the Robe Trough where the prominent reflector at the base of the upper unit of the Otway Group laps onto basement. South of this hingeline, the lower unit of the Otway Group wedges in, apparently without major faulting. Further south a reversal of dip results in truncation of the Otway Group-lower unit beneath the upper unit, to shot-point 210 where the prominent reflector separating the upper and lower units of the Otway Group is replaced by the discordant(?)near basement reflector or series of reflectors

Haematite Explorations Lines SS2 and SA2 (plate 10)

Between SP90 and SP129 sediments of the upper unit of the Otway Group rest on and locally abut an undulating reflector which probably represents the top of basement. The regional dip of this reflector is basinward and no significant hingeline exists about which the sediments either thicken or plunge more steeply to the southwest. This regional basinward dip continues in the SS2 section to SP25 where the prominent reflector fades out, but disconnected reflections south of SP25 indicate that the sequence continues to dip basinward.

Trends extrapolated from sections to the east indicate that at least the upper part of the Otway Group-lower unit does not extend to this section. However, Haematite Explorations (1965) have interpreted basement at 11000 feet near SP50 so there is either considerable thickening of the upper unit of the Otway Group or else the sedimentary section equivalent to the interval between 2.3 and 3.5 seconds at SP30 on line SS29 is developed in this western end of the Robe Trough.

<u>Haematite Explorations Lines SS22, SS24, SS25, SS26, SS27</u>
(plates 12 and 13)

These survey lines are all orientated roughly perpendicular to the coast between Geltwood Beach and the Victorian border. They are not described separately because there are certain structural and sedimentary features common to all.

The most pronounced feature consists of the persistent northeasterly dip of the Mesozoic sediments. Some local reversals of dip form anticlinal structures which are superimposed on this trend. However, the off-shore area may be regarded as the south limb of a syncline whose axis passes approximately through Geltwood Beach and Mt. Salt. The north limb of this syncline is represented approximately by the south flank of the Beachport-Kalangadoo Basement High.

The remaining distinctive feature in these seismic sections is the pronounced unconformity between the northeast dipping Mesozoic sequence and the flat or southwest dipping Lower Tertiary sequence. This unconformity in the SS22 section is at much the same level as the Lower Tertiary-Upper Cretaceous boundary (Bureau of MineralResources, Geology and Geophysics (Ed.) 1965) at a point within two miles of Geltwood Beach No. 1. Extrapolation across a distance of two miles appears to be reasonably sound because the unconformity remains relatively flat in this area.

Similarly, in the SS25 section, the unconformity is at about the same level as the base of the Bahgallah Formation in Mt. Salt No. 1, six miles to the north. The SS27 section gives additional control near the Nelson Bore where the unconformity occurs at 3800 feet, comparable to the depth to the base of the Bahgallah Formation in the Nelson Bore (3746 feet according to Hawkins and Dellenbach 1963) 3.5 miles to the northeast.

Unfortunately neither an unconformity nor a prominent reflector marks the base of the Upper Cretaceous sequence in the off-shore area, except perhaps where the horizon at this level in Geltwood Beach No. 1 corresponds to a slight discordance in the SS22 section.

In the SS25 section the approximate base of the Upper Cretaceous sequence is ghosted from an assumed depth of about 10,000 feet near the coast, to the point where this horizon is truncated near the continental margin. Attempts to follow the base of the Upper Cretaceous southward from SS22 along the SA13 and SA14 sections to the SS25 section give anomalous results so the distribution and relationship of the Upper Cretaceous to the Lower Cretaceous in the off-shore area is at this stage largely unknown.

Recent well information suggests that the Mt. Salt Well was completed above the Belfast Mudstone, consequently the base of the upper Cretaceous sequence is probably at a considerable depth below 10,000 feet at Mt. Salt and the off-shore limit of Upper Cretaceous sediments shown on plate 16 may be too conservative. ~~because the Belfast Mudstone is not included in the interpretation.~~

Unconformities are also lacking in the Tertiary sequence which includes sediments of Paleocene, Eocene and Oligocene age. Consequently, the sequence is not readily differentiated except for an apparent separation of two successive sets of foresets near the southern end of the SS25, SS26, SS27 sections. These foresets extend a short distance down the continental slope and are limited on the landward side by a linear feature roughly parallel to the axis of the syncline in the Mesozoic sediments (plate 16). Foresets are not present north of the point where this linear feature intersects the continental margin (plate 16).

STRUCTURAL FEATURES OF THE GAMBIER EMBAYMENT

The major structural components of Gambier Embayment established in the literature are the Padthaway Horst (Sprigg, 1952), later designated the Padthaway Ridge by O'Driscoll (1960, Vol. I, p.17), and the Penola gravity trough (Sprigg, 1961). In addition, the gravity high features at Beachport and Kalangadoo, although not formally named, have been interpreted by a number of authors as basement highs relative to the deeper sedimentary areas to the north and south.

Interpretation of the seismic records supports the above configuration and gives much new information on the structures bounding and controlling these features.

Northern Margin of Gambier Embayment

The northern margin of the Gambier Embayment is not defined from surface geology due to the Pleistocene to Recent sediments that cover it. Consequently, geophysical methods, including aeromagnetic and gravity contour maps have been used to drive a good approximation of the boundary between shallow and deep basement (Sprigg, 1952). However, the seismic surveys not only pin-point the boundary more accurately, but show the structure and distribution of the sediments, which in turn gives valuable information on the nature of the basin margin.

In this regard the seismic surveys indicate that the Tertiary strata are not markedly affected by the major structural elements of the Gambier Embayment, therefore the distribution of only the Cretaceous sediments need be considered. Consequently the northern margin of the Gambier Embayment is herein defined as the present northern limit of Lower Cretaceous sediments.

The structural character of this margin varies considerably from west to east, being modified in some cases by the proximity of the Robe-Penola Trough. However, it is possible to divide the basin margin into three broad zones which are structurally distinctive from each other, but are essentially homogeneous internally.

Between survey lines SS28 and SS29 (plate 16) the Robe Trough is 5-10 miles south of the basin margin and the upper unit of the Otway Group sediments wedges up the flank of the trough before spreading out in a thin layer over an undulating basement surface on the Padthaway Ridge (plate 8). This basement surface has a regional dip basinward of about 200 feet per mile, compared with about 500 feet per mile down the flank of the Robe Trough.

There is no apparent structure controlling the northern extent of the upper unit of the Otway Group sediments in the shallow basement area, as truncation beneath the Lower Tertiary sediments, wedge out, and onlap up the slope are the controlling factors. However, the northern limit of the lower unit of the Otway Group is controlled by the structural boundary of the basin, toward which it wedges out, and is truncated.

Between survey line SA3 and the CK line there is a completely different structural pattern. Here the northern edge of the Robe Trough is faulted about two miles south of the northern boundary of the Lower Cretaceous sediments. In marked contrast to the configuration further west, the Otway Group-lower unit sediments dip toward, and appear to abut this fault or hingeline (plate 7). If this is correct, the throw on the marginal fault must be several thousand feet at least. The Otway Group-upper unit sediments, also in contrast to the position further west, dip steeply basinward, along the basin margin and as a result are completely truncated beneath the Tertiary strata several miles north of the fault.

This configuration is consistent with the closely spaced gravity contours along this part of the basin margin (plate 20).

There is a gradation between the above structural configuration of the basin margin and the configurations to the west and east. East of the CK seismic line, the northern margin of the Gambier Embayment becomes more complex because a shelf area up to 18 miles wide, separates the Penola Trough from the Padthaway Ridge. Basement highs superimposed on the shelf increase the complexity.

The lower unit of the Otway Group, in this zone wedges against a hingeline that represents the boundary between the Penola Trough and the shelf area. Wedge-out is most pronounced adjacent to the local basement highs, whereas truncation may be the major cause for thinning of the Otway Group lower unit across the shelf elsewhere. Another feature of this hingeline consists of of the steepened dips with which is associated truncation of the upper unit of the Otway Group and reduction of the lower part of the Tertiary sequence.

There is little seismic control across the basin margin north of the shelf area, but trends in sections that approach the boundary north of Lucindale indicate that the Lower unit of the Otway Group wedges out or is truncated completely, several miles south of the margin of the basin. At RN 210 (Plate 4) and SB 8 (Plate 3) the lower unit of the Otway Group appears to be faulted off against basement, but the upper unit extends a further 6 miles before being in turn faulted off at RN 243. The fault at RN 210 may have a throw of as much as 1,000 feet whereas the throw at RN 243 is about 400 feet. There is no other definite control on the northern limit of the Otway Group upper unit except that the fault at RN 243 is approximately in line with the linear northern boundary of Lower Cretaceous outcrops in Western Victoria. This extrapolated line meets the north-east trending boundary several miles south of the Papineau Rocks basement outcrops, and is in agreement with the shallowing basement indicated on the Namco RG refraction line. Although the boundary as interpreted is linear, it is not suggested that it represents a major fault.

In this regard the marginal area between Lucindale and Struan is expected to be structurally similar to the area north of the Robe Trough and west of survey line SA 3, where Otway Group upper unit sediments gradually wedge out and are eroded off over a shallow, undulating basement surface which has a gentle regional basinward dip.

The basinward dip of the shelf south of the basin margin between Lucindale and Struan is difficult to define because of its irregular structure. However, the somewhat generalised contours on the base of the upper unit of The Otway Group (Plate 18) indicate a regional dip of about 100 feet per mile to the S.S.W. This dip increases to about 400 feet per mile down the northern flank of the Penola Trough. Dips in the lower unit of the Otway group are generally greater, reaching 1,000 feet per mile down the southern flanks of the local basement highs.

Southeast of Struan, the Penola Trough approaches the Padthaway Ridge and the structural configuration is similar to that north of the Robe Trough near SA3.

In conclusion, therefore, it is apparent that the northern margin of the Gambier Embayment is a composite feature. Previous concepts which invoked a single major fault are over-simplified because the basin margin varied with time in both character and position. Initially the boundary followed approximately the present northern limit of the lower unit of the Otway Group (plate 16). This boundary has the form of a hingeline, south of which the basement surface is steeply downwarped and faulted. The Robe and Penola Troughs represent over-deepened areas with thickest Otway Group-lower unit sediments. Where the Robe Trough approaches the northern margin of the basin, the lower unit of the Otway Group is faulted against basement and the pene-contemporaneous marginal structure is obscured.

Faulting also limits the lower unit of the Otway Group to the east on the RN and SB lines, but it is not clear from the sparse reflections whether the movement was wholly post sedimentar or in part contemporaneous. Considerable wedge-out is indicated toward these faults.

Sedimentation of the Otway Group-upper unit was not significantly affected by the hingeline that limits the lower unit. However, the relatively steep dips associated with the hingeline has resulted in progressive truncation of the Otway Group-upper unit to the north. Some of the reduced section in this zone is due to wedge-out and off-lap up the flank of the basin, but much of the intermediate and lower parts of the upper unit of the Otway Group in some areas extend across the hinge zone, onto the shallow, gently dipping basement surface on the southern flank of the Padthaway Ridge. Where the gravity gradient is most pronounced between theCK line and the SA3 line, the northern flank of the basin becomes relatively steep and the upper unit of the Otway Group is almost completely eroded off the Padthaway Ridge.

Consequently the northern boundary of the Gambier Embayment may be broadly divided into a structural margin and a sedimentary margin. The structural margin represents the hingeline on the southern boundary of the Padthaway Ridge, from which the basement surface plunges steeply basinward, and also corresponds broadly to the northern limit of Otway Group-lower unit sediments. The sedimentary margin is not defined by any marked structure, but represents the present northern limit of Cretaceous sediments. The sedimentary margin thus defined only approximates the original basin limits, as post sedimentary structural movement and erosion has greatly modified the original distribution of the Otway Group-upper unit on the Padthaway Ridge.

The Robe-Penola Trough

The Robe-Penola Trough comprises an area of thickened Mesozoic sediments and follows very closely the distribution of the gravity low which extends northwestward from Casterton in Victoria to the vicinity of Robe (plate 16). From Robe, the trough acquires a W.S.W. to westerly alignment.

Seismic data indicate that the Robe-Penola Trough represents a negative area bounded to the north partly by the structural margin of the embayment (Robe Trough) and partly by an irregular hingline, about which the lower unit of the Otway Group wedges-in strongly (Penola Trough). These wedges on the SB line near SP50 (plate 3) have the form of successive foresets built out into the trough from the shelf area.

The southern margin of the trough is bounded by a basement high complex which extends from southeast of Kalangadoo to Beachport. Seismic refraction survyes indicate that this southern margin is faultedin the Kalangadoo area (Namco 1965). In addition, information from the Kalangadoo No. 1 Well indicates that the lower unit of the Otway Group does not extend across the present basement high. This, together with the absence of Otway Group-lower unit sediments in the Beachport Well (based on distribution of floral assemblages, Evans, 1966) which bottomed within 1,000 feet of basement according to gravity data (Kendall, 1966), indicates that the lower unit of the Otway Group must be confined to the Robe-Penola Trough, except for the shelf area between Lucindale and Struan.

Offshore seismic sections which show that the lower unit of the Otway Group is progressively truncated to the south, support this interpretation. In addition, the line that represents the southern limit of the reflector at the top of the lower unit of the Otway Group in the off-shore area, is in line with the northern margin of the Kalangadoo-Beachport Basement High. Consequently this line probably represents the southern margin of the Robe Trough where the lower unit of the Otway Group is truncated down to basement.

Continuity of the Robe-Penola Trough is strongly suggested by the RN line where the lower unit of the Otway Group wedges in markedly across the gap between the Lucindale High and a northern projection of the Kalangadoo-Beachport Basement High. The B, C and E seismic lines, together with the gravity low betweeen the Penola and Robe Troughs, confirm that the two are continuous, although of different orientation. However, it is convenient for some purposes to divide the Robe-Penola Trough into its two regional constituents.

Depth to basement in both regions of the Robe-Penola Trough from seismic refraction surveys is similar, reaching a maximum of 10-12,000 feet within several miles of the trough margin. As the depth to the base of the upper unit of the Otway Group within the trough averages 4-5,000 feet, the average thickness of the lower unit in the Penola-Robe Trough must be 5-8,000 feet. However, Maureira (in Haematite Explorations Pty Ltd 1965) interpreted a major fault near the axis of the Robe Trough which has downthrown to a depth of 20,000 feet a sedimentary segment conformable with, and presumably part of the lower unit of the Otway Group. Movement along this fault must be of the order of 7,000 feet.

Contrary to the distribution of the lower unit which thickens to at least 5,000 feet within several miles of the trou margin, Otway Group-upper unit sedimentation does not appear to be significantly affected by the Robe-Penola Trough. In addition to the consistent thickness, the attitude of the Otway Group-upper unit within the trough is relatively flat. Progressive truncation is indicated up the north flank of the trough, but no dislocation or truncation can be detected along the southern flank.

Consequently, in view of the much greater thickness of the Otway Group-upper unit sediments at Geltwood Beach, the area of the Robe-Penola Trough may be regarded as a stable region, perhaps a stable shelf, during deposition of the Otway Group-upper unit.

THE KALANGADOO-BEACHPORT BASEMENT HIGH

The gravity contour map (plate 20) shows a marked gravity high centred on Beachport, with subsidiary highs to the north and east. Interpretation of gravity data (Kendall, 1966) suggests that basement is at 5,500 at Beachport and at 3,200 feet in the high to the north. Southeast of Beachport, toward and beyond Kalangadoo, there are several more gravity highs which coincide with relatively shallow basement. Seismic refraction surveys indicate that the basement depth near Kalangadoo is at 9,500 feet, however, the Kalangadoo No. 1 well entered pre-Mesozoic sediments at 6530 feet below sea level, indicating that the area contains relatively thin Mesozoic sediments.

As stated in the previous section, the relatively thin Mesozoic sequence on the Kalangadoo-Beachport Basement High results from downfaulting, truncation, wedge-out, or non-deposition of the lower unit of the Otway Group. The upper unit on the other hand, extends over the high without any noticeable thinning or arching.

In the offshore area there is no gravity data to determine whether the ridge extends west of Beachport. However, survey lines SA12, SS29, SA10, and SS18 show that the lower unit of the Otway Group rises and is truncated, possibly with some wedge-out, to the south. The reflector representing the boundary between the upper and lower units of the Otway Group disappears about 10 miles north of Beachport and is replaced by a discordant, deeper reflector which corresponds closely to the depth to basement calculated from aeromagnetic data (Haematite Explorations 1965). This basement or near basement reflector is at about 6,000 feet adjacent to the Beachport High and plunges steeply to the west (plate 16). However, the plunge of the (?) near basement reflector is slight to the northwest, parallel to the line showing the limit of the reflector marking the boundary between the upper and lower units of the Otway Group (plate 16).

Consequently it is considered that the structural equivalent of the Kalangadoo-Beachport High extends in subdued form offshore northwest of Beachport, and probably merges with the seaward extension of the Padthaway Ridge. Basement in the off-shore high exists at a greater depth than in the basement high on land, but nevertheless forms the southern boundary to the present distribution of Otway Group-lower unit sediments. This sedimentary boundary is probably the main factor unifying the Kalangadoo-Beachport High as the various components of the high may have different origins. In this regard a fault bounds the north side of the ridge in the Kalangadoo area, whereas no significant faulting is indicated in the offshore area. In both of these areas the lower unit of the Otway Group does not extend over the high due to post-sedimentary faulting and erosion. The Beachport group of highs on the other hand may represent in part, pre-sedimentary basement highs similar to the Lucindale High, about which the Otway Group-lower unit wedges out.

The south flank of the high is very poorly defined by seismic surveys, but appears from refraction Surveys (Namco, 1964), to be tilted gently basinward south of Kalangadoo. At or near the position of the Tartwarp Fault, another hingeline or fault causes an increased plunge of the basement surface to the south where it reaches at least 16,000 feet at Mt. Salt. This hingeline probably extends northwest to beyond Geltwood Beach.

Seismic surveys do not define the southern margin of the off shore ridge except perhaps near SP115 on the SA10 survey line (plate 9) where a marked steepening of the southward dip takes place.

The Mt. Salt Syncline

This is an area where the basement surface, based on seismic refraction and gravity data reaches a depth of 16-19,000 feet. Consequently the deeper sediments are beyond the depth of good seismic reflection response and very little information is available on the structure of the basin in this area. As mentioned in the previous section, the Beachport-Kalangadoo Basement High dips gently south toward a hingeline roughly coincident with the Tartwarp Fault. South of this hingeline the post Otway Group sediments dip more steeply and thicken considerably. The lack of deep reflection makes it impossible to determine whether the upper unit of the Otway Group wedges in south of this hingeline also.

In the off-shore areas the Upper and Lower Cretaceous sediments are structurally conformable and exhibit a marked shoreward dip component. This dip reversal results in progressive southward truncation of the Mesozoic sediments beneath the flat or seaward dipping Tertiary sequence. Consequently the southern boundary of the Lower Cretaceous sediments is an erosional boundary, probably essentially parallel to the line of dip reversal shown in plate 16, but modified by the continental slope. The line of dip reversal delineates the axis of a regional synclinal structure herein termed the Mt. Salt Syncline, which extends from the Victorian border to beyond Geltwood Beach, where it merges with the east-west Robe Trough. The axis of this syncline represents the axis of thickest preserved Upper Cretaceous sedimentation within the Gambier Embayment and may also represent the axis of thickest Otway Group-upper unit sediments. Whether this axis also represents the axis of thickest original deposition is not clear due to the post-depositional uplift and truncation. The uplift is roughly parallel to, and may be associated with the formation of the present continental margin. The age of the uplift must be essentially post-Cretaceous, but part at least may have been contemporaneous with deposition during the Upper Cretaceous.

The northern limb of the Mt. Salt Syncline on the other hand may simply represent the Lower Cretaceous depositional slope modified by some contemporaneous down warping; especially south of the Tartwarp Fault. This slope appears to be independent of the Kalangadoo basement high, but is affected by faulting associated with arching of the Lower Cretaceous strata, near Krongart. Similar structures are defined north of the Beachport-Kalangadoo High near MP140 (plate 4) at the northern end of the Namco B line (plate 5), and possibly at CK50 (plate 3). In addition, marked thickening and increased basinward dip of the base of the upper unit of the Otway Group takes place along the hingline north of the Beachport high in the offshore area. These structures may be continuous or on echelon, but together form the northern margin of the syncline and also limit the onshore distribution of Upper Cretaceous sediments.

Additional evidence for the pre-Upper Cretaceous age of the feature that limits the northern extension of Upper Cretaceous sediments, is given in the Namco B line (plate 5) where the Upper Cretaceous strata appear to abut and wedge out northward against the Lower Cretaceous sediments. This contrasts markedly with the relationship on the southern limb of the syncline where the Upper and Lower Cretaceous sediments are conformable, except to the southwest of Geltwood Beach where a slight discordance appears on line SS22 (plate 12).

The above-described structures represent the basic structures thus far defined, that form the frame work of the Gambiez Embayment. All of these structures which are of Mesozoic age, controlled deposition of the Mesozoic sediments. However, younger structures undoubtedly controlled deposition of the Tertiary sediments, but these are relatively subdued and are not adequately defined by the sparse shallow reflections in the seismic sections.

Generallly the Lower Tertiary sediments were deposited on a relatively regular surface with a gentle southwesterly dip. Weak depressions in this surface which hold thicker Lower Tertiary deposits generally conform to areas of thickest pre-Tertiary deposits (plate 19), e.g. the Lower Tertiary sequence thins across the shelf area north of the Penola Trough in sympathy with thinning of the upper and lower parts of the Otway Group.

Numerous small-scale faults are indicated in the seismic sections and in outcrop (Sprigg, 1952) but these mostly represent post Middle-Tertiary movements which consequently do not affect sedimentation. However, O'Driscoll (1960, Vol. I, p. 97) considered that wedge-out of the Gambier Limestone north of S.A. Oil Wells bore in section 598, hundred of Caroline, may be due to contemporaneous faulting.

BRIEF NOTES ON STRUCTURAL EVOLUTION OF THE GAMBIER EMBAYMENT

The Gambier Embayment as defined by the seismic surveys, is a composite feature due to continued tectonic activity during sedimentation. However, intensity and distribution of tectonic activity varied in time and consequently it is difficult to subdivide the embayment into precise structural features without recourse to the dimension of time.

The main structural features are Jurassic to Cretaceous in age and include the Padthaway Ridge, the Robe-Penola Trough, including the "shelf" area, the Beachport-Kalangadoo High, and the Mt. Salt Syncline to the south.

The Padthaway Ridge has remained a positive structure throughout the history of the Gambier Embayment, and the hingeline along the south flank of the ridge controlled sedimentation during the Upper Jrassic to Lower Cretaceous at least. Some overlap of Lower Cretaceous sediments tookplace along the southern flank, but it was not until the Middle Tertiary that any large area of the Padthaway Ridge received accumulations of sediment.

Upper Jurassic downfaulting and downwarping along the southern flank of the Padthaway Ridge resulted in an elongate trough or basin, of which the Penola-Robe Trough represents an eroded remnant. The orientation and nature of the southern flank of this sedimentary area is not known, because post-sedimentary uplift of the Beachport-Kalangadoo High has truncated the Otway Group-lower unit sediments which were deposited in this period. However, continued negative movements along the northern flank of the basin has preserved the approximate original extent of the lower unit of the Otway Group in this area.

Consequently the area from the Beachport-Kalangadoo High to the Padthaway Ridge comprises one structural unit of the Gambier Embayment, which received sediments of the upper Jurassic to lowermost Cretaceous lower unit of the Otway Group. The Robe-Penola Trough represents an overdeepened area within this structural unit which received a greater thickness of sediment than the "shelf" area between Lucindale and Struan. Haematite Explorations (1965) have interpreted a large scale fault just north of the axis of the Robe Trough which downfaulted about 7,000 feet of sediment against basement to the north. Reflections from these sediments are structurally conformable with reflections from the lower unit of the Otway Group. If both reflector groups are referable to the Otway Group-lower unit, it would indicate considerable over-deepening of the Robe Trough relative to the Penola Trough.

The Beachport-Kalangadoo High which forms the southern flank of the Penola-Robe Trough, was at least in part an area of sedimentation during the Upper Jurassic to Lower Cretaceous and therefore represents part of the original negative area of the Gambier Embayment. However, uplift at or toward the end of Otway Group-lower unit deposition, created a new structural unit in the form of a basement high, from which the lower unit of the Otway Group was subsequently removed by erosion.

By the beginning of Otway Group-upper unit sedimentation the Beachport-Kalangadoo High had become consolidated with the Robe-Penola Trough to form a shelf area which received an average of 3-4,000 feet of sediment compared with more than 8,000 feet to the south. Later faulting and warping is essentially independent of the Beachport-Kalangadoo High. Some renewed downwarp occurred along the structural margin of the basin, but this zone also became stabilized during deposition of the upper unit of the Otway Group. The new area of deposition south of the Beachport-Kalangadoo High is poorly defined, especially in the offshore area where post depositional uplift and erosion has obscured the original relationships. Information along the northern margin of this negative feature is also meagre, but the available information indicates that the hingeline responsible for part at least of the downwarp to the south, is several miles north of the Beachport-Kalangadoo BasementHigh. In this regard, considerable thickening of the upper unit of the Otway Group takes place in the offshore area basinward of the line defining the southern limit o the reflector marking the top of the lower unit of the Otway Group. This limit is north of the culmination of the Beachport High on the survey line SA12 at least. Onshore a definite southward dip in the Otway Group-upper unit strata develops south of the hingeline which controlled Upper Cretaceous sedimentation nea Krongart. Whether this hingeline represents partly Lower Cretaceous or entirely post-Lower Cretaceous movement is not positiv ly determined, but it is apparent that the Beachport-Kalangadoo High became part of the downwarped flank of the main area of deposition during the Upper Cretaceous and possibly during part of th Lower Cretaceous.

Negative movement of the southern area relative to the Robe-Penola Trough continued into the Upper Cretaceous when sedimentation in the Gambier Embayment was confined entirely south of the hingeline passing through Krongart. The thickest deposits in this area were laid down south of the Tartwarp Fault. However, toward the end of the Upper Cretaceous period, uplift in the offshore area produced a broad synclinal structure (Mt. Salt Syncline) with its axis almost parallel to the edge of the continental shelf. This uplift probably occurred during formation of the present continental margin, as the truncated southern limb of the syncline forms the platform or shelf on which the Tertiary sediments have been deposited. In addition, no major post-Mesozoic structural features are as yet defined. The Tertiary sediments appear to be built out across a gently seaward sloping surface in which minor depressions represent compaction of the older sediments perhaps with some latent warping and small scale faulting along the old hingelines.

Post-depositional faults mapped in the Tertiary outcrops (Sprigg, 1952) are generally of small magnitude and may represent similar adjustments which were possibly intensified by late Tertiary uplift in the Palaeozoic fold belts of the Adelaide and Tasman Geosyncline.

The sequence of tectonic events outlined above has an interesting and significant pattern which may be divided into 3 major phases.

The first phase consists essentially of the following sequence of events:

Downwarp along the northern margin of the basin during the Upper Jurassic.

Rapid accumulation of a thick sequence of Upper Jurassic to Lower Cretaceous sediments in the depressed area.

Uplift in lowermost Cretaceous time, followed by erosional truncation down to basement of the southern part of the depressed area. This uplift formed the Beachport-Kalangadoo High and a broad synclinal structure preserved as the Robe-Penola Trough. These components later became consolidated to a large extent with the basement area to the north.

The second phase comprises a similar sequence of events in a new area immediately south of the Robe-Penola Trough.

The main downwarp in this case which received the greatest thickness of sediment took place during the Lower Cretaceous along a hingeline independent of, but near the southern limit of the eroded syncline (Robe-Penola Trough). Contemporaneous downwarp along the basin margin, probably coupled with some regional southward tilt, resulted in an intermediate thickness of sediment on the shelf area of the Robe-Penola Trough, and a thin sequence on the southern part of the Padthaway Ridge.

During the late Upper Cretaceous time, uplift of the southern part of the new depressed area again resulted in formation of a broad syncline (Mt. Salt Syncline) the southern limb of which was subsequently deeply truncated. In both cases the truncation is most pronounced toward the northwest. This synline in turn became consolidated with the Robe-Penola Trough and the Padthaway Ridge, forming a shelf area during the third phase in the development of the Gambier Embayment.

The third phase is partly a repetition of the second phase, but under more stable conditions. Regional subsidence and tilt to the south again resulted in deposition of an intermediate thickness of sediment (Tertiary) on the shelf area formed by interconsolidation of the earlier downwarps. However, the third phase differs from the second phase in that the negative area to the south is non-continental.

It is apparent therefore, that the Gambier Embayment evolved by differential block faulting as two successive downwarps during the Jurassic and Cretaceous. Each of these downwarps was successively uplifted from the south and fused to the continent. The last of these processes formed the present continental margin during the uppermost Cretaceous or lowermost Tertiary. Much of the movement along the major faults probably took place during deposition. In addition, much of the uplift and truncation of the southern part of the downwarped areas may have taken place contemporaneously with deposition of regressive facies in the central part of the downwarps.

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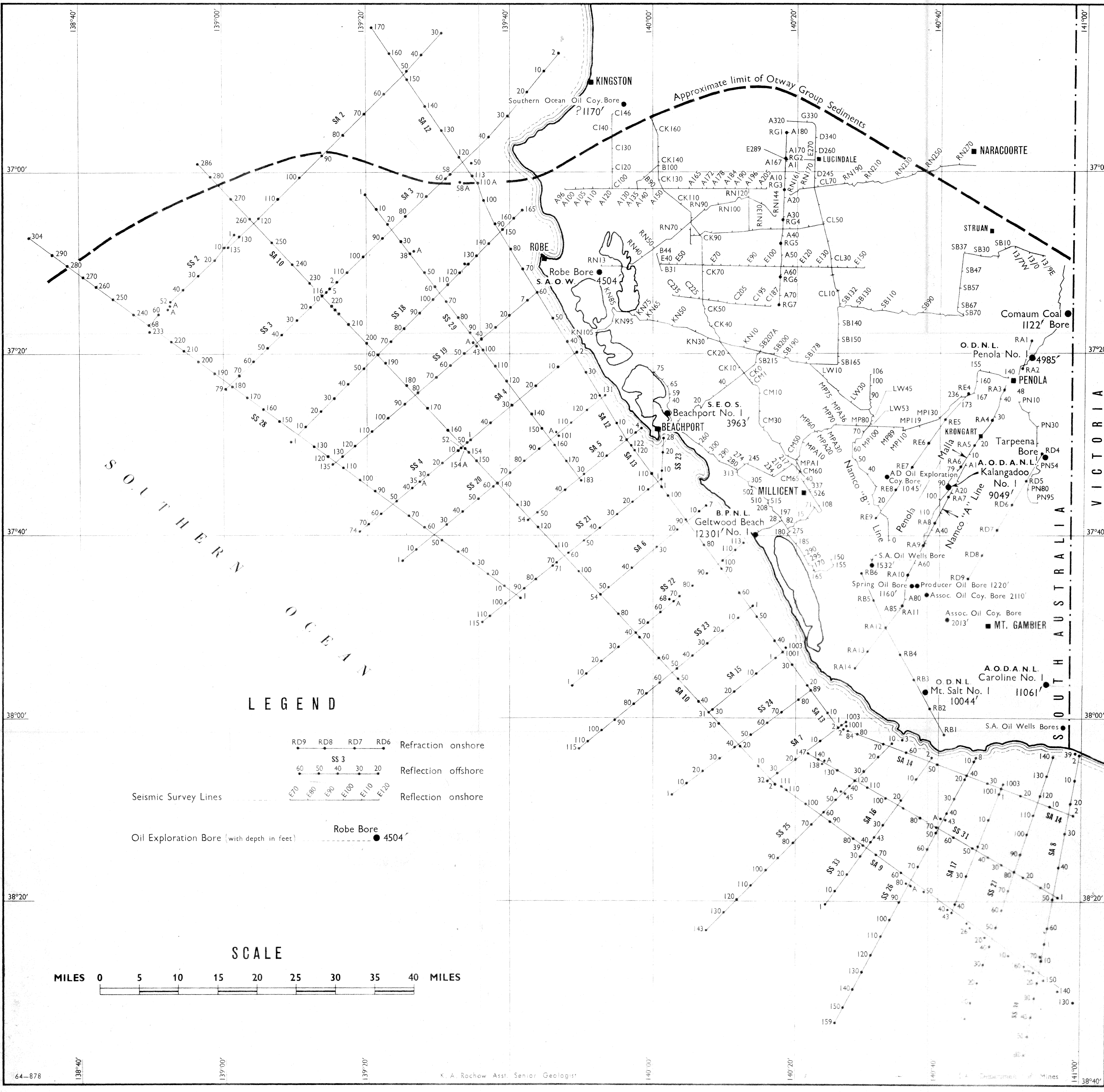


Reduce to 11 3/16 inches

LOCALITY MAP
SHOWING SEISMIC SURVEY LINES AND OIL EXPLORATION WELLS

PLATE 1

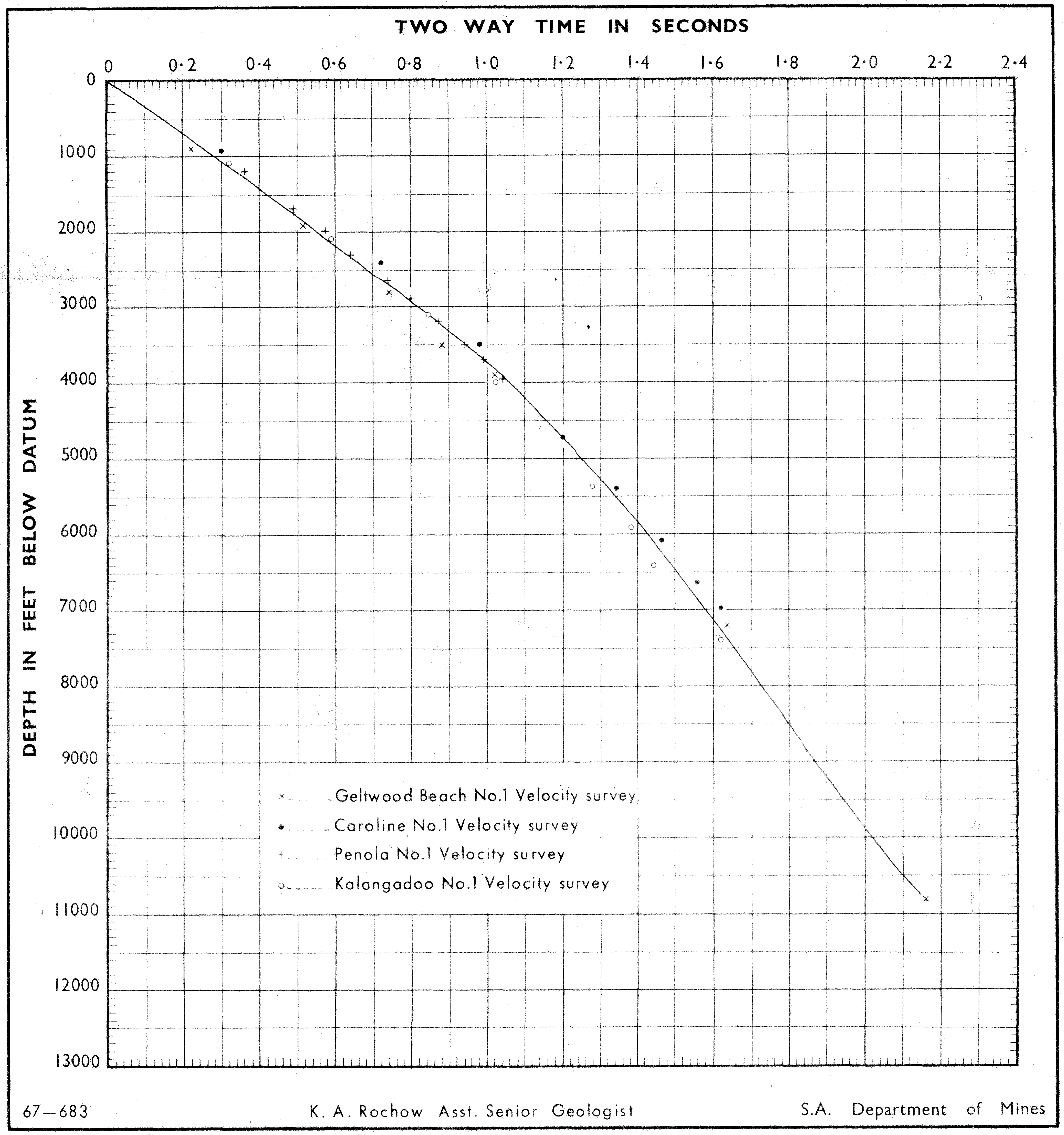


PLATE 2

PLATE TIME - DEPTH CURVE

PLATE 2 *OTWAY BASIN*

M.L. 67-683/4
Kde 2·10·67

64-882

K. A. Rochow Asst. Senior Geologist

S.A. Department of Mines

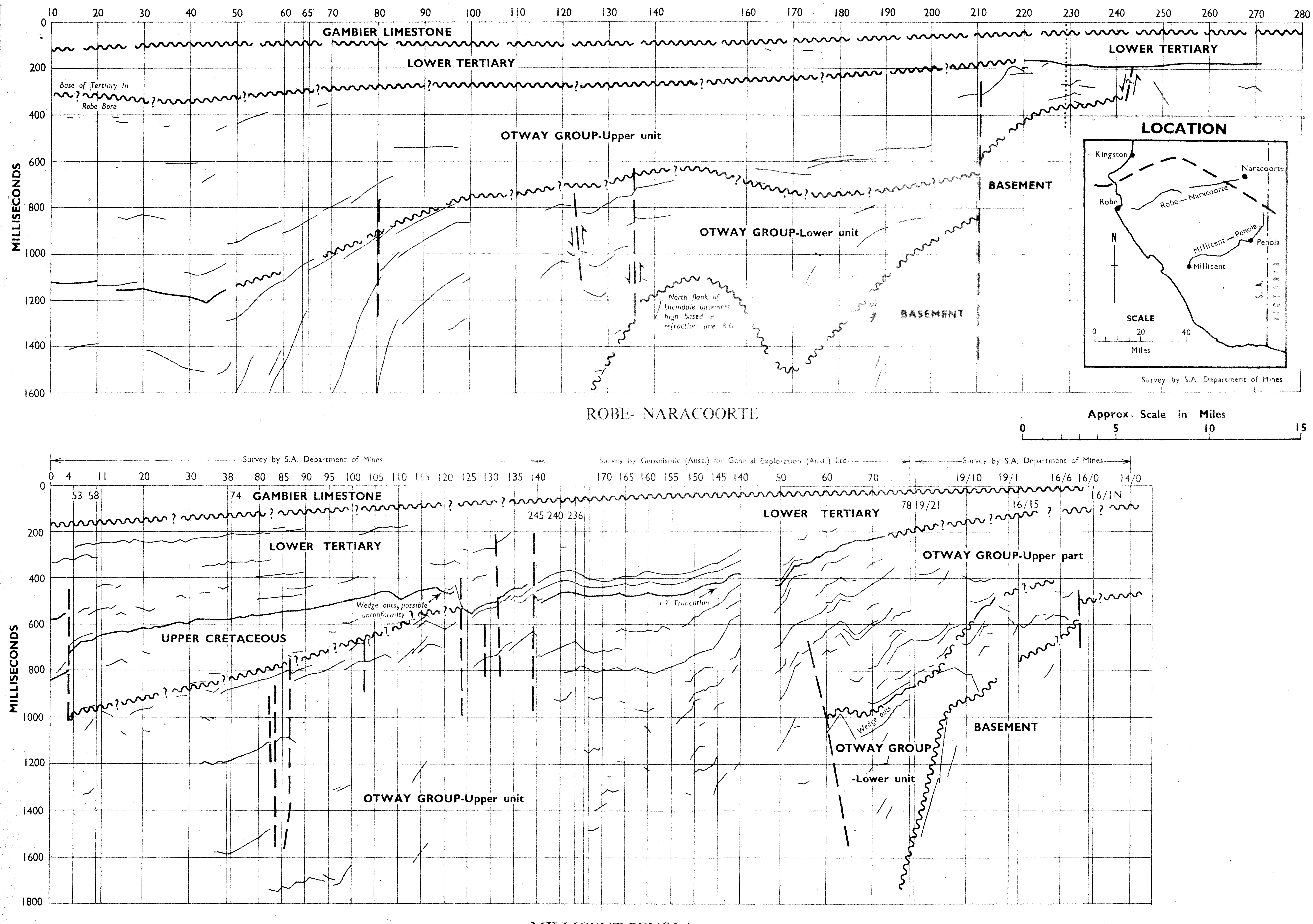
Reduce to inches

PLATE 3

ML 64-882/4
Kde
8·2·67

PLATE GEOLOGICAL INTERPRETATION OF STRUAN-BEACHPORT AND GELTWOOD BEACH-KINGSTON SEISMIC TIME SECTIONS

PLATE 3 OTWAY BASIN



OTWAY BASIN

GEOLOGICAL INTERPRETATION OF ROBE-NARACOORTE SEISMIC TIME SECTIONS

PLATE 4

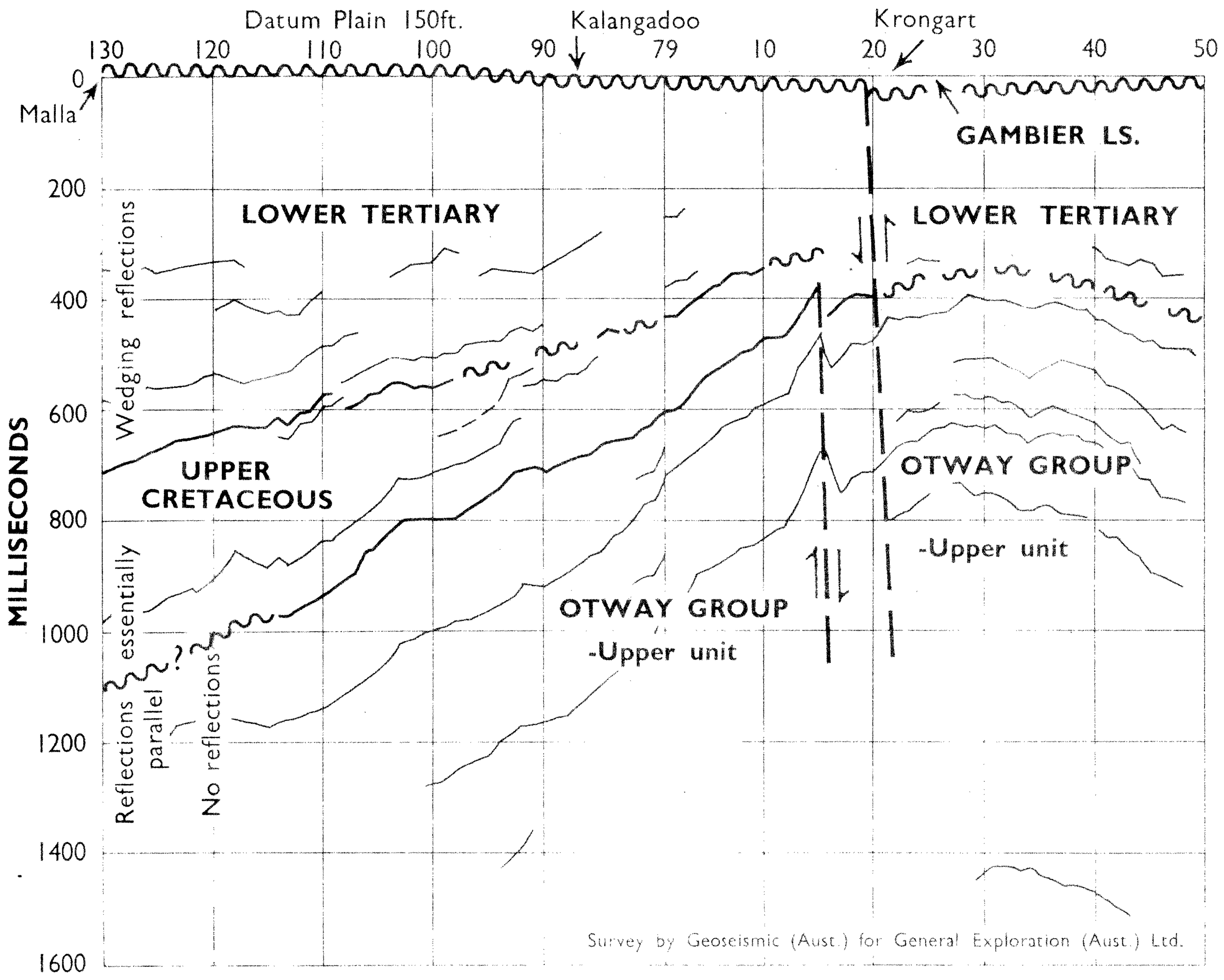
64-881/4 Kde

Reduce to inches

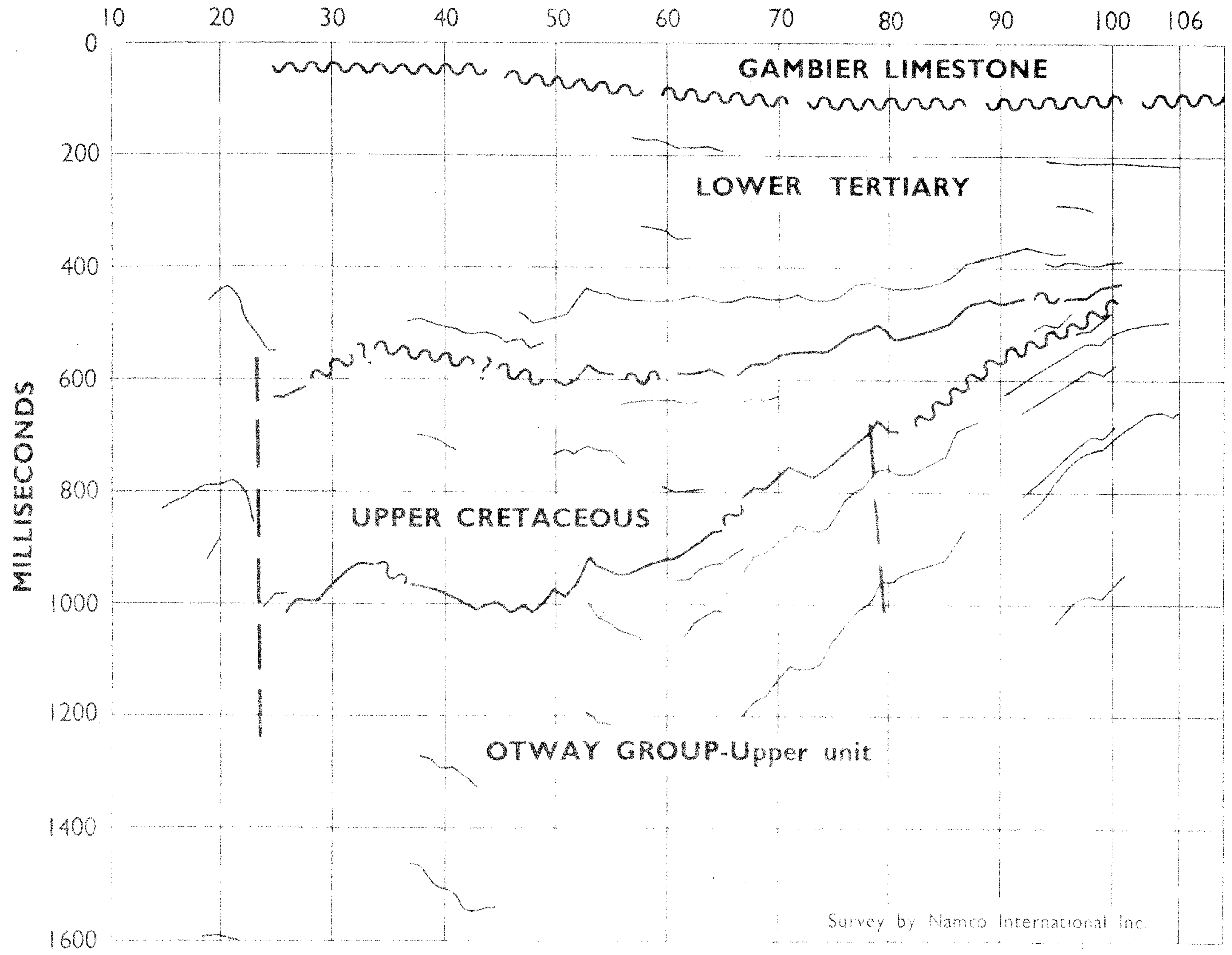
64- 881

K. A. Rochow Asst. Senior Geologist

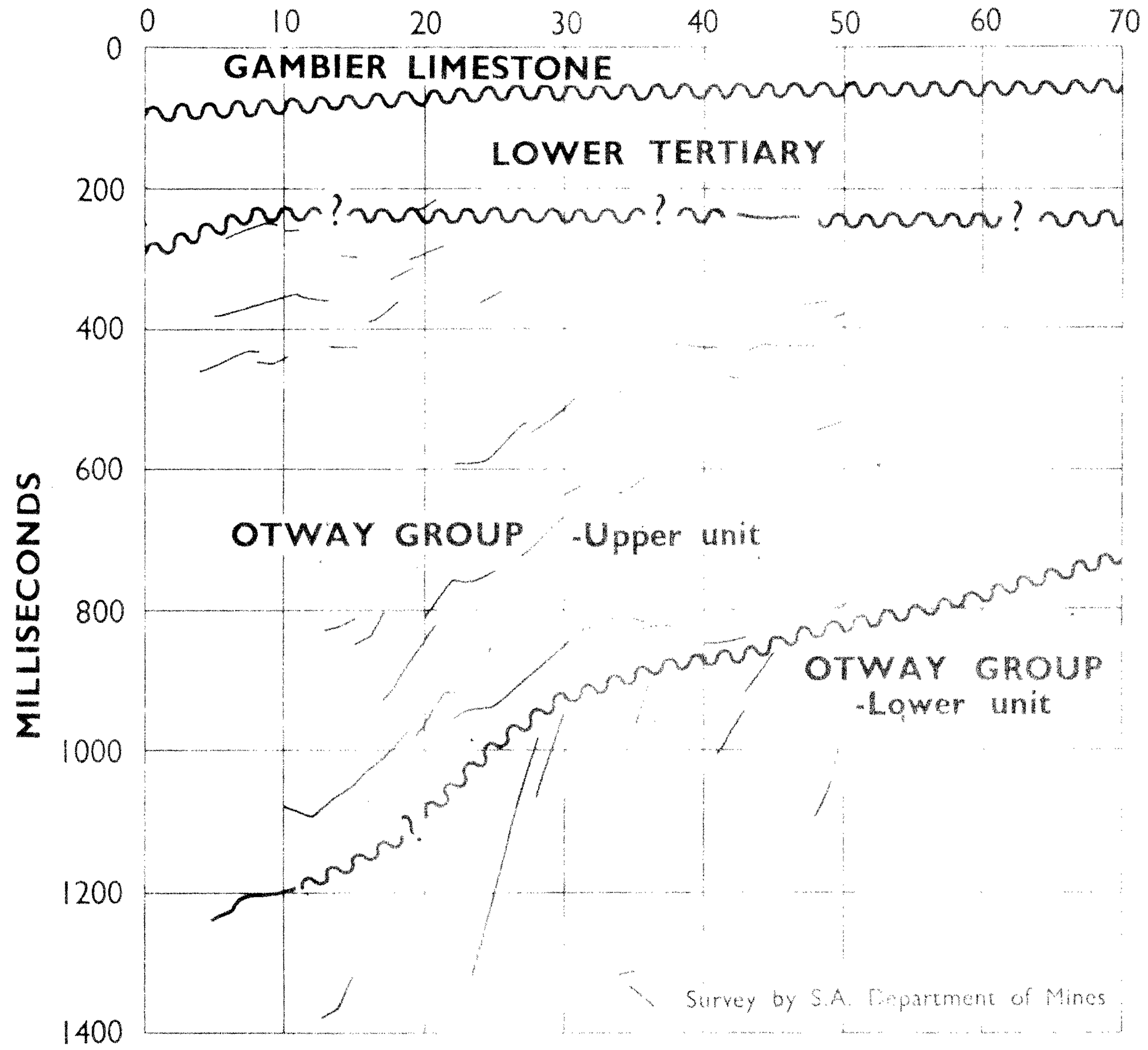
S.A. Department of Mines



PENOLA-MALLA



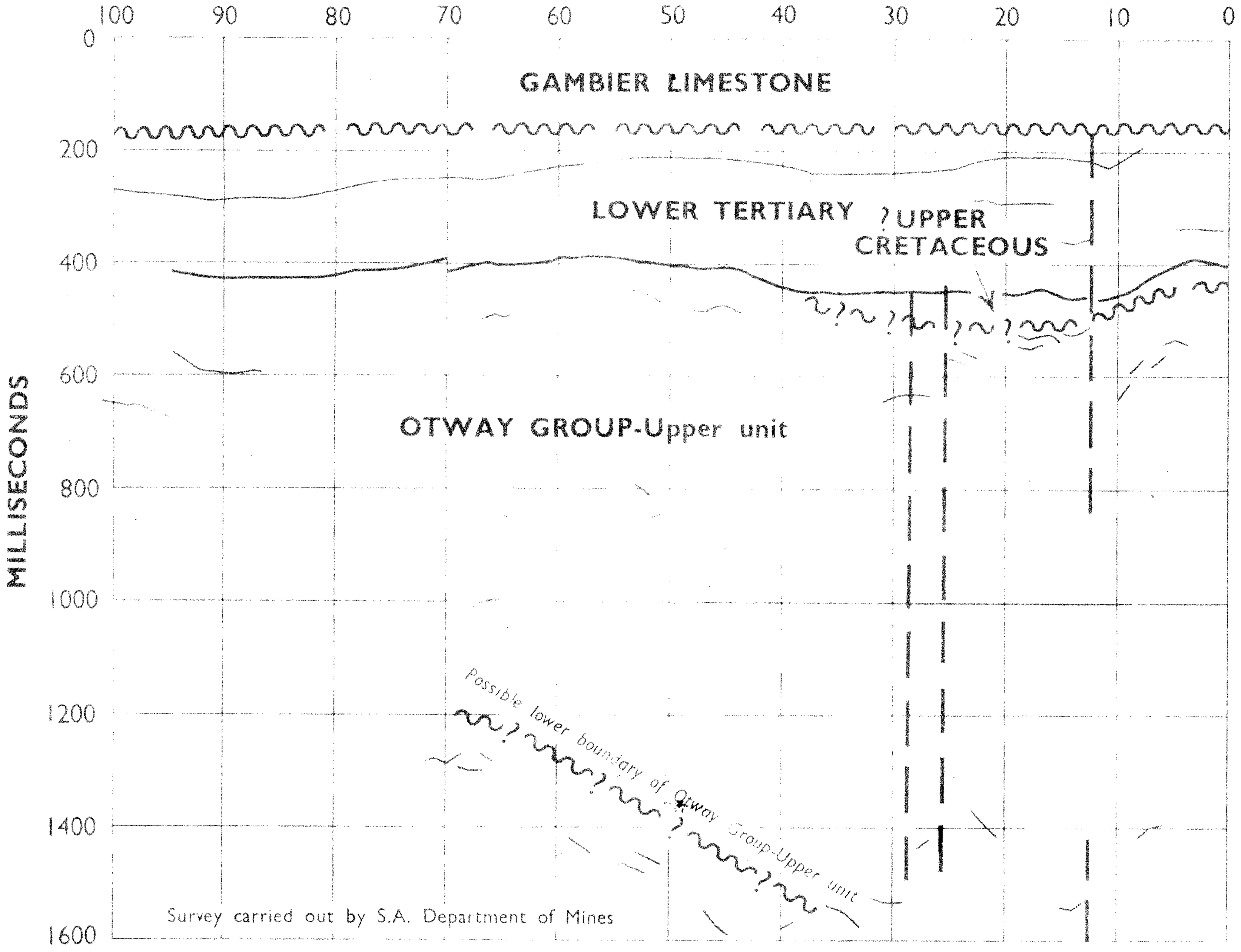
NAMCO B LINE



CALLENDALE-LUCINDALE

Approx. Scale in Miles

0 5 10 15



KANGAROO INN - NORA CREINA BAY

64-887

K. A. Rochow Asst. Senior Geologist

S.A. Department of Mines

Reduce to inches

PLATE GEOLOGICAL INTERPRETATION OF PENOLA-MALLA, NAMCO B LINE, CALLENDALE-LUCINDALE, AND KANGAROO INN-NORA CREINA BAY SEISMIC TIME SECTIONS

PLATE 5

OTWAY BASIN

ML 64-887/4 Kde 8·2·67

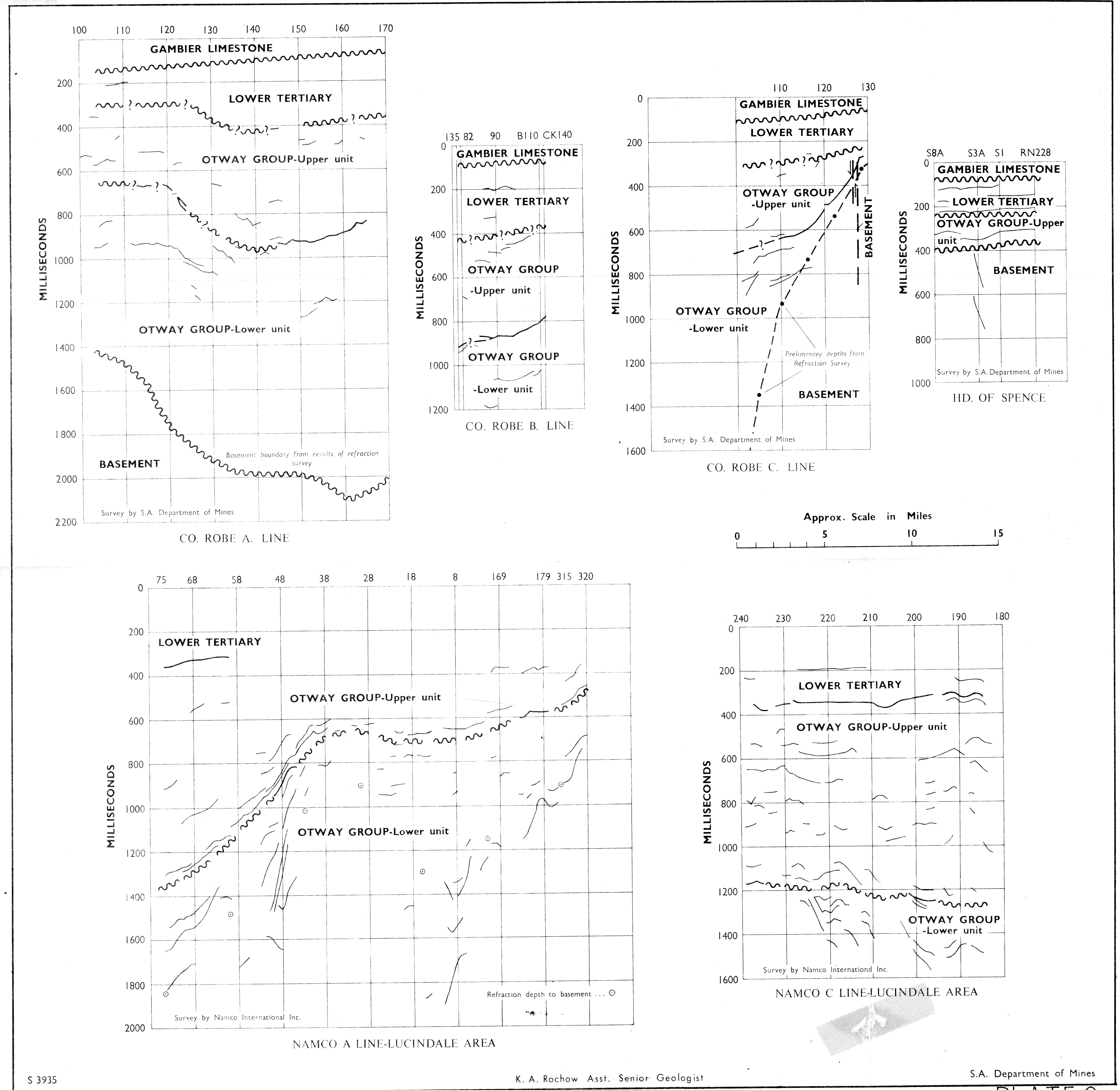


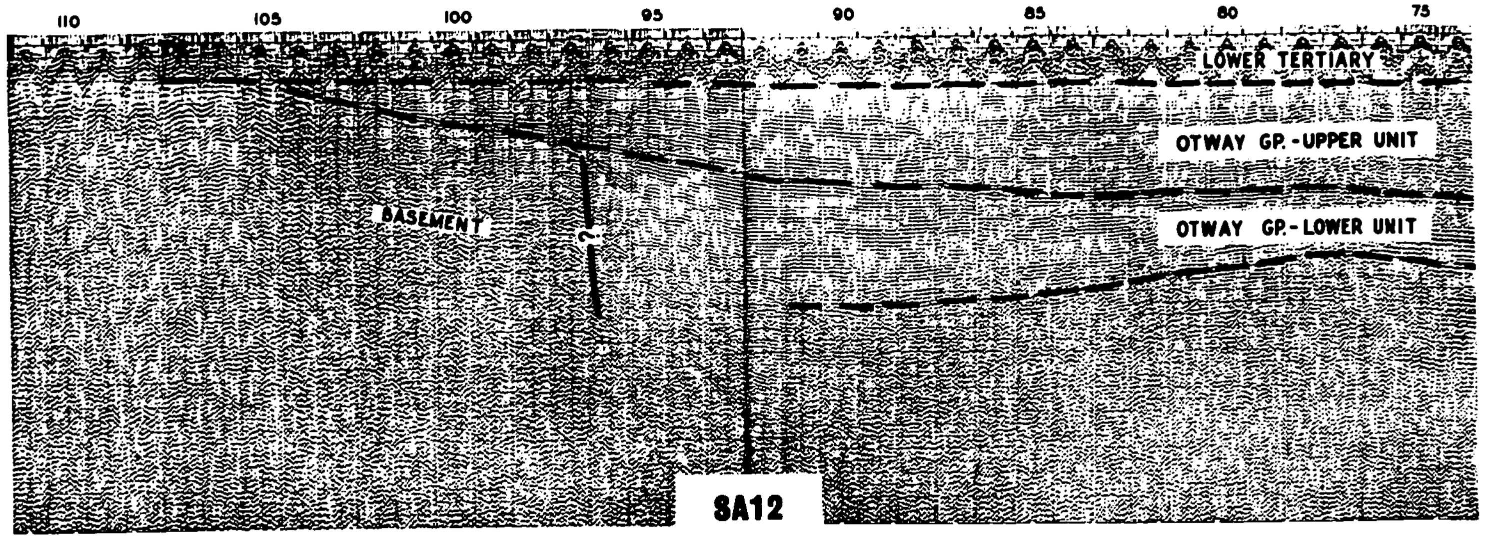
PLATE 6

Reduce to inches

PLATE GEOLOGICAL INTERPRETATION OF 6 SEISMIC TIME SECTIONS FROM THE NORTHERN PART OF THE OTWAY BASIN

PLATE 6

S3935/4
Kde
8·2·67



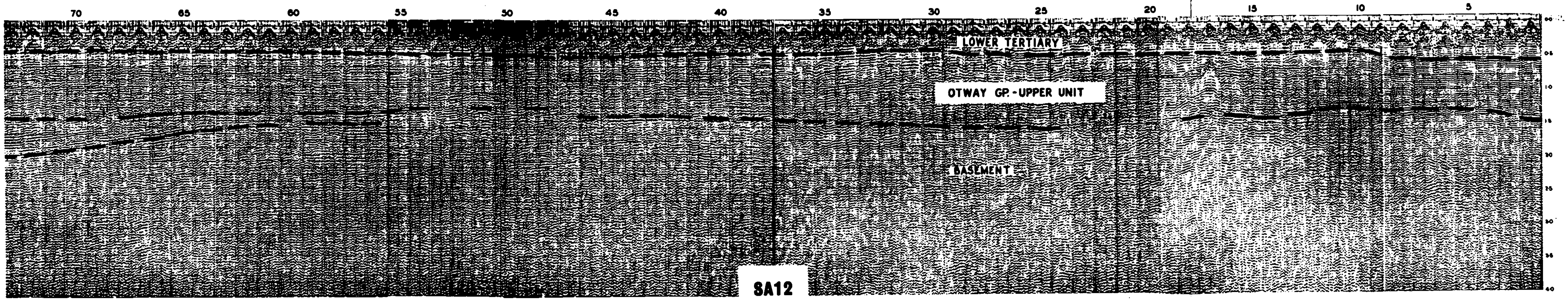


Plate 7. Geological interpretation of Haematite Explorations seismic time section SA12.

PLATE 7

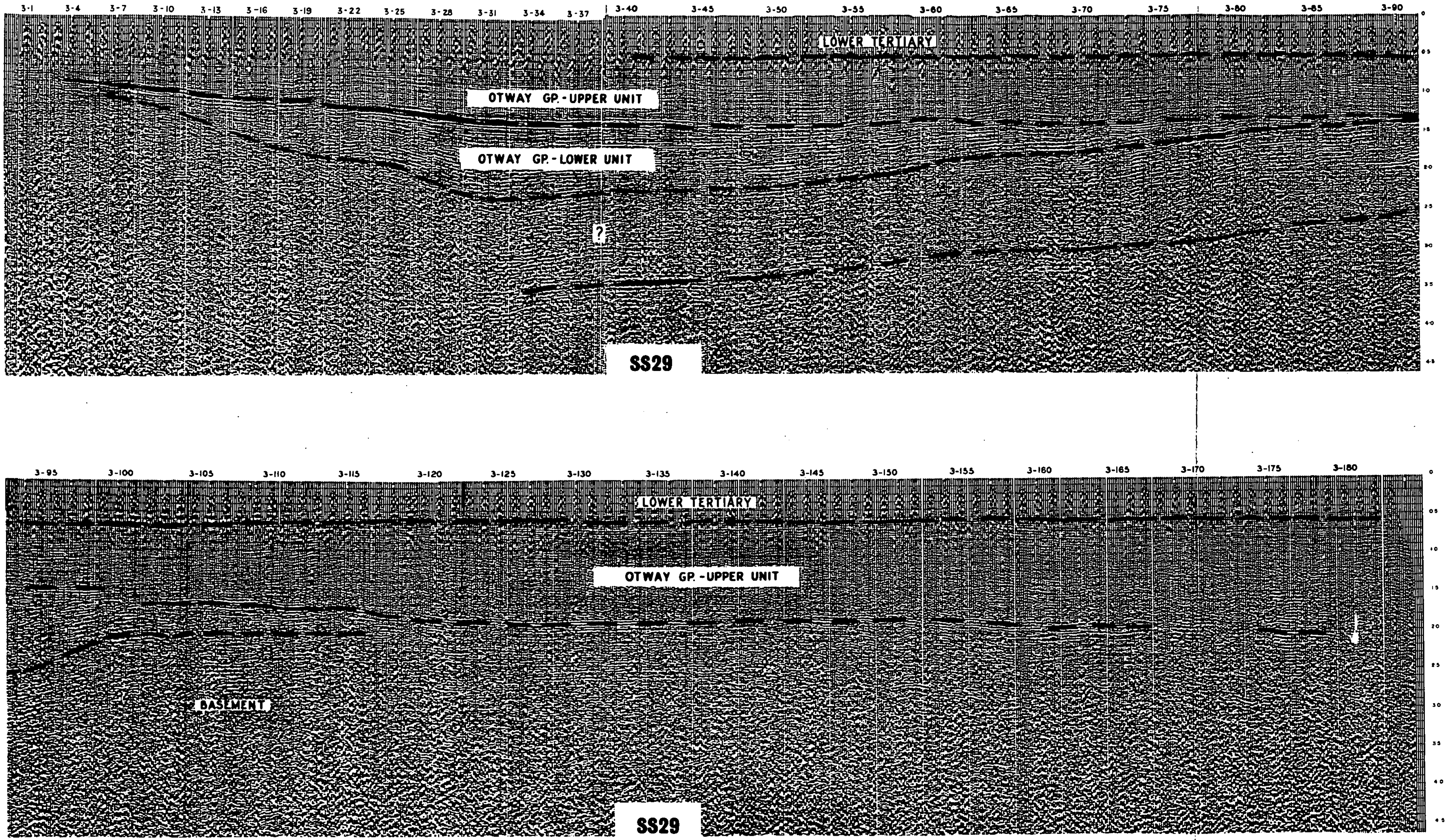


Plate 8. Geological interpretation of Haematite Explorations seismic time section SS29.

PLATE 8

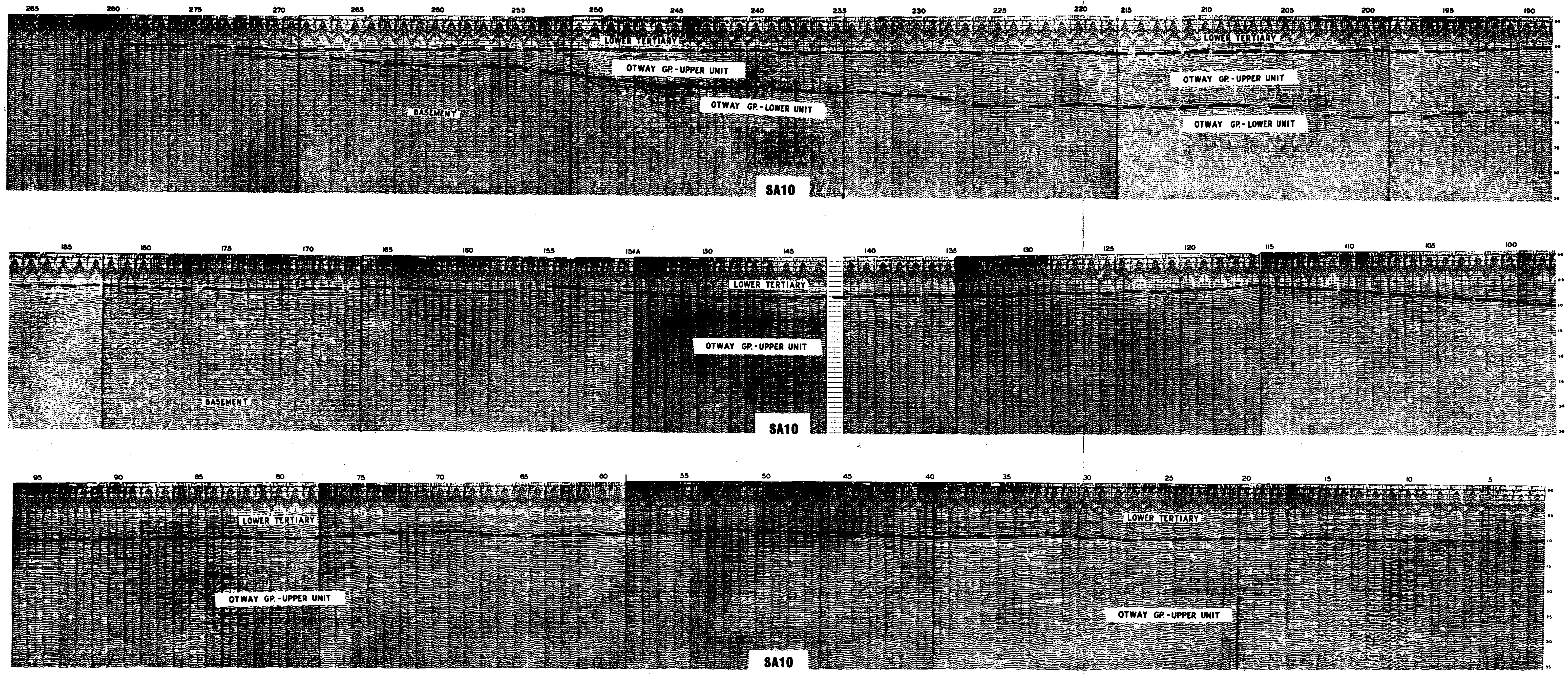
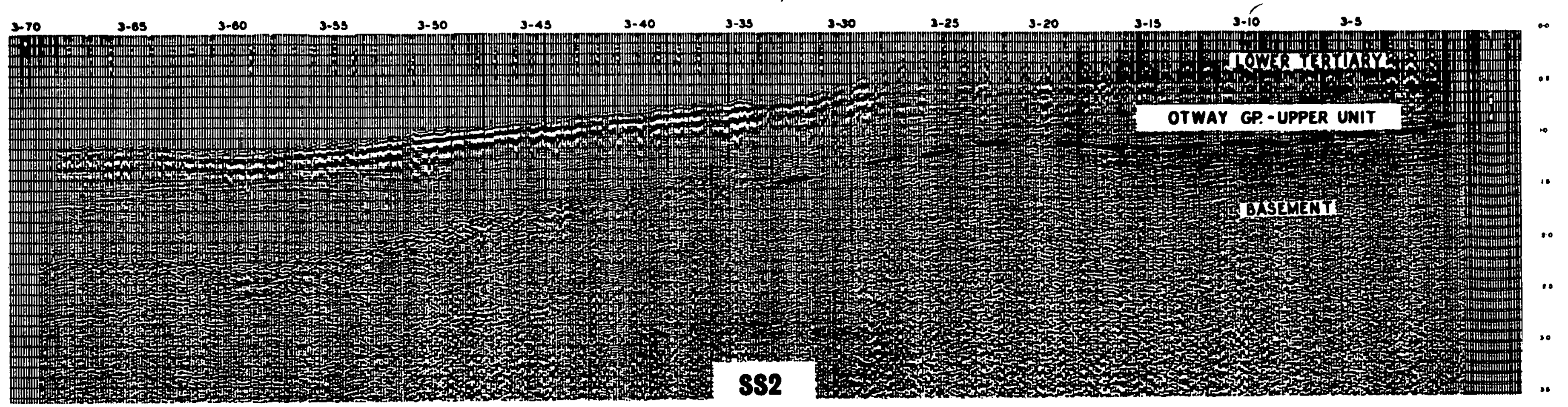
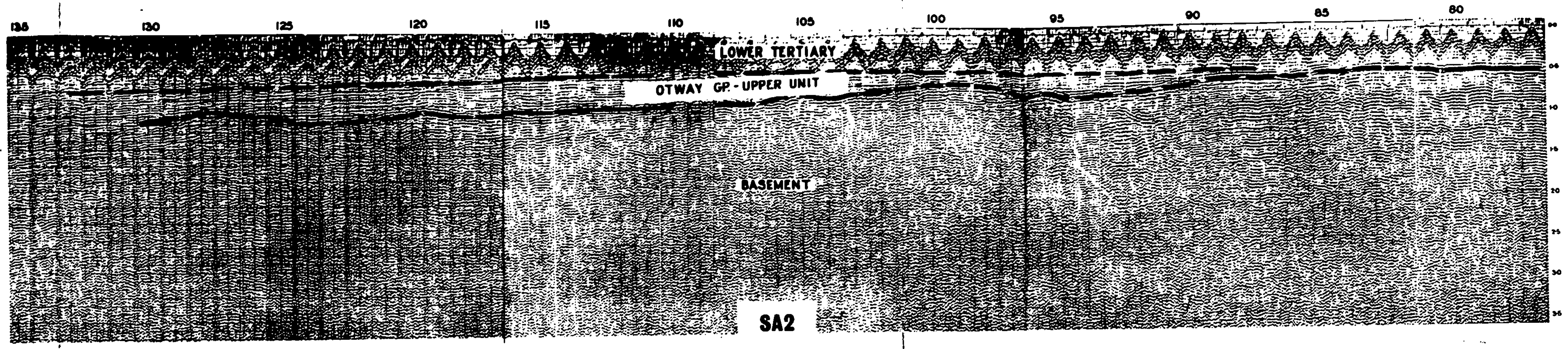
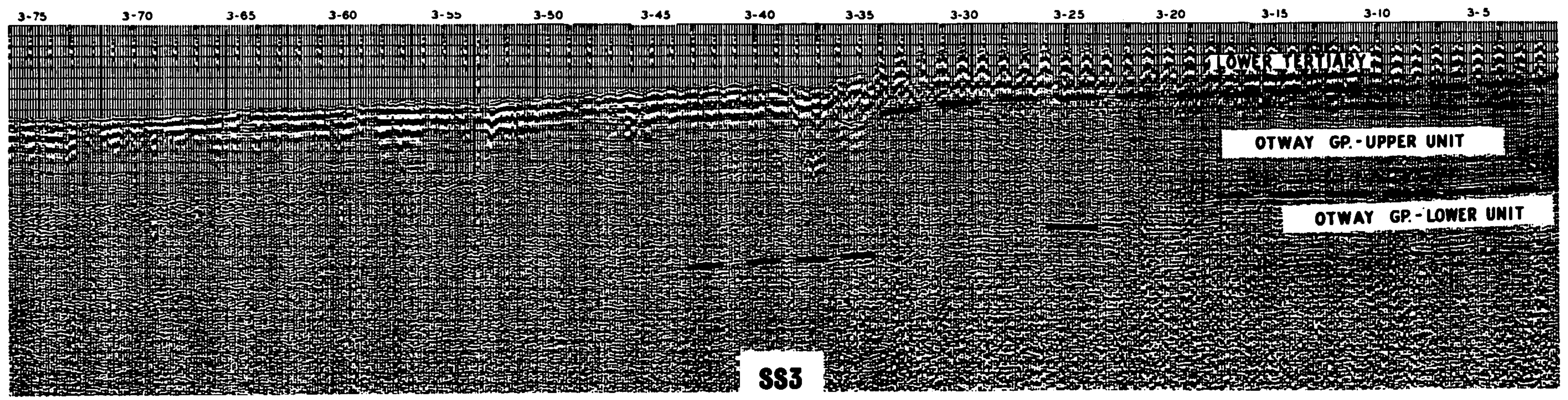


Plate 9. Geological interpretation of Haematite Explorations seismic time section SA10.

PLATE 9







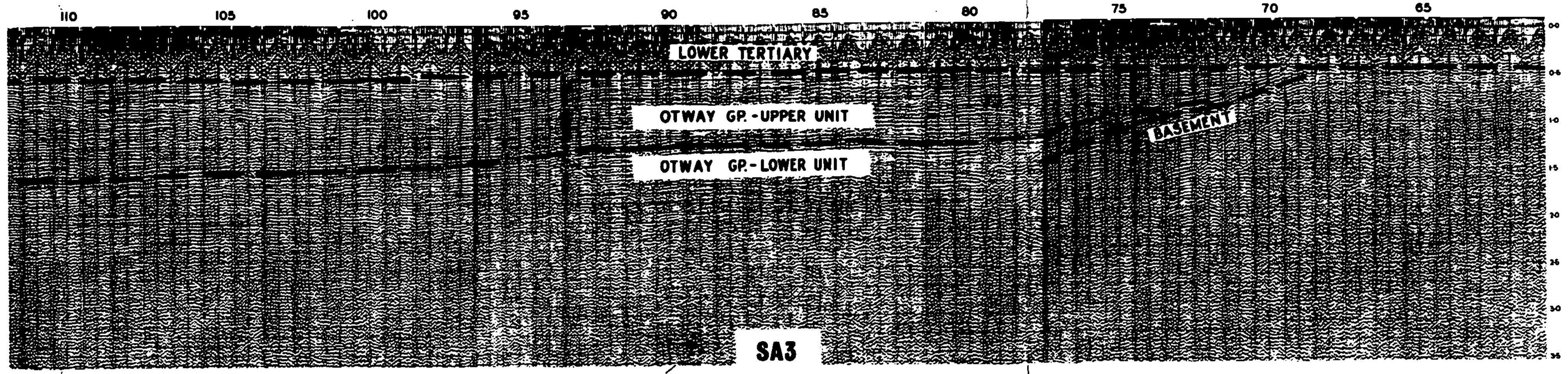
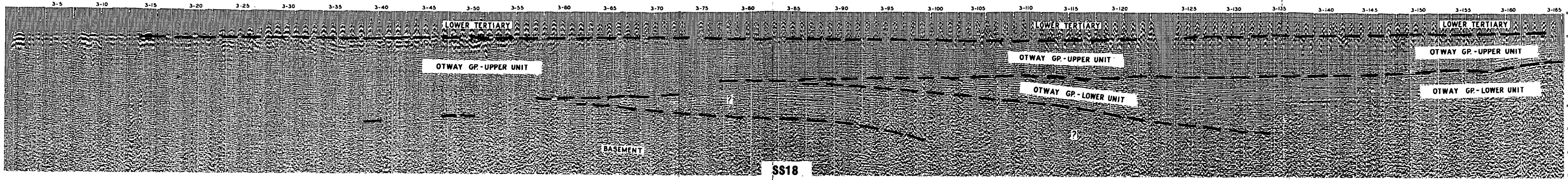
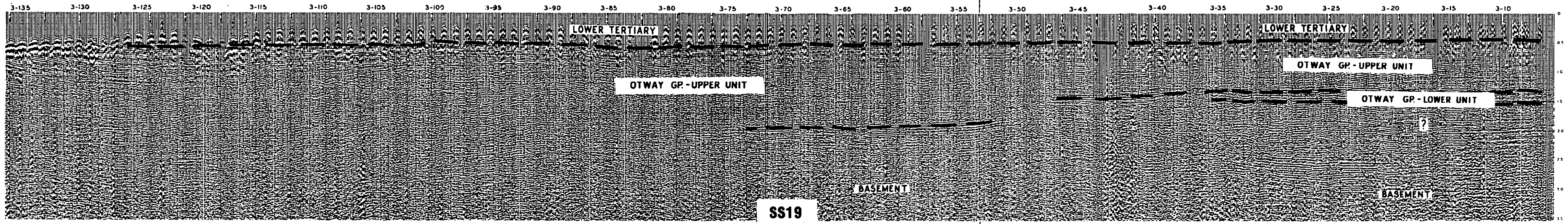


Plate 10. Geological interpretation of Haematite Explorations seismic time sections SA2, SS2, SA3, SS3.

PLATE 10





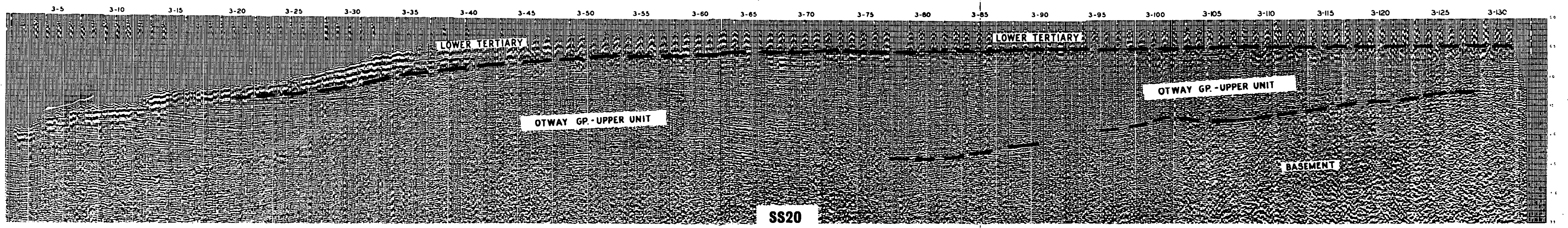


Plate 11. Geological interpretation of Haematite Explorations seismic time sections SS18, SS19, SS20.

PLATE 11

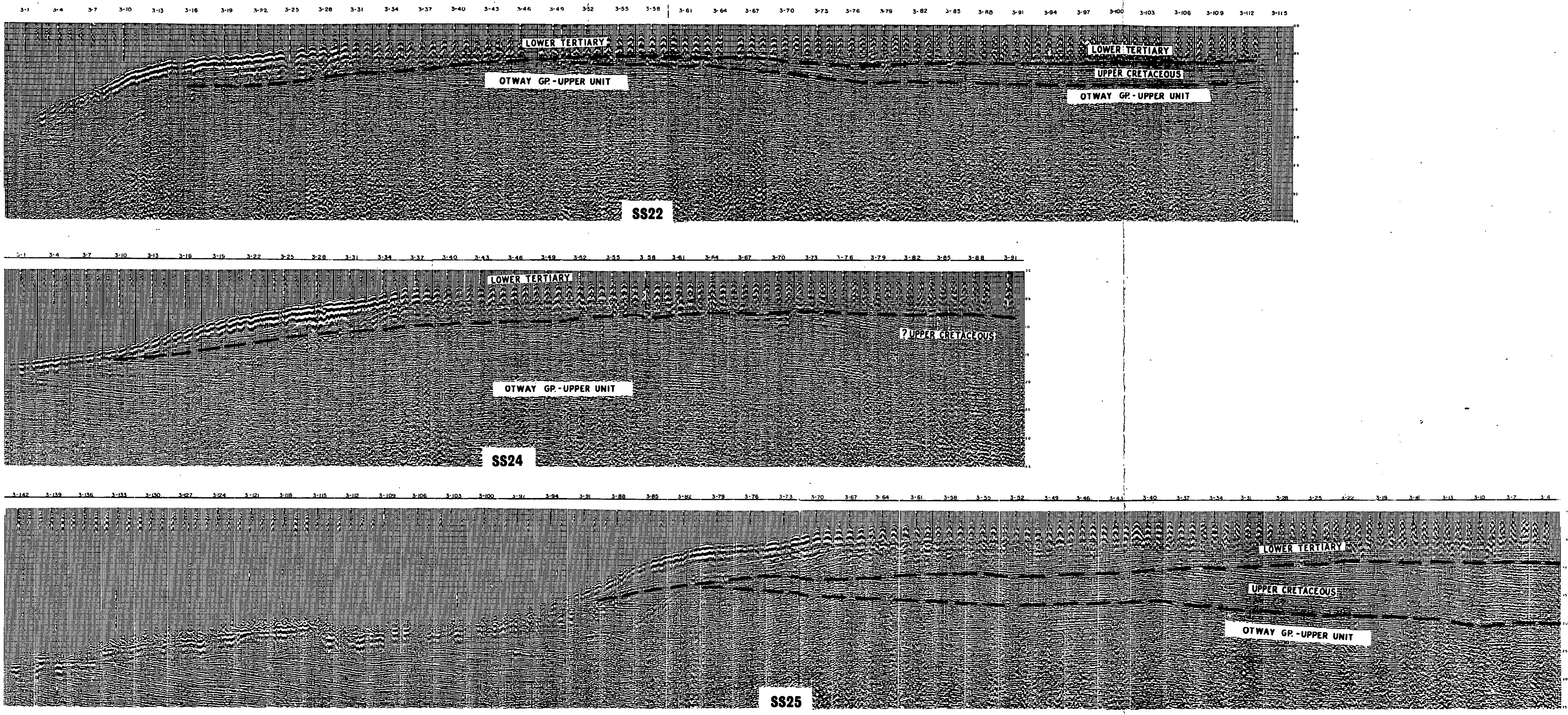


Plate 12. Geological interpretation of Haematite Explorations seismic time sections SS22, SS24, SS25.

PLATE 12

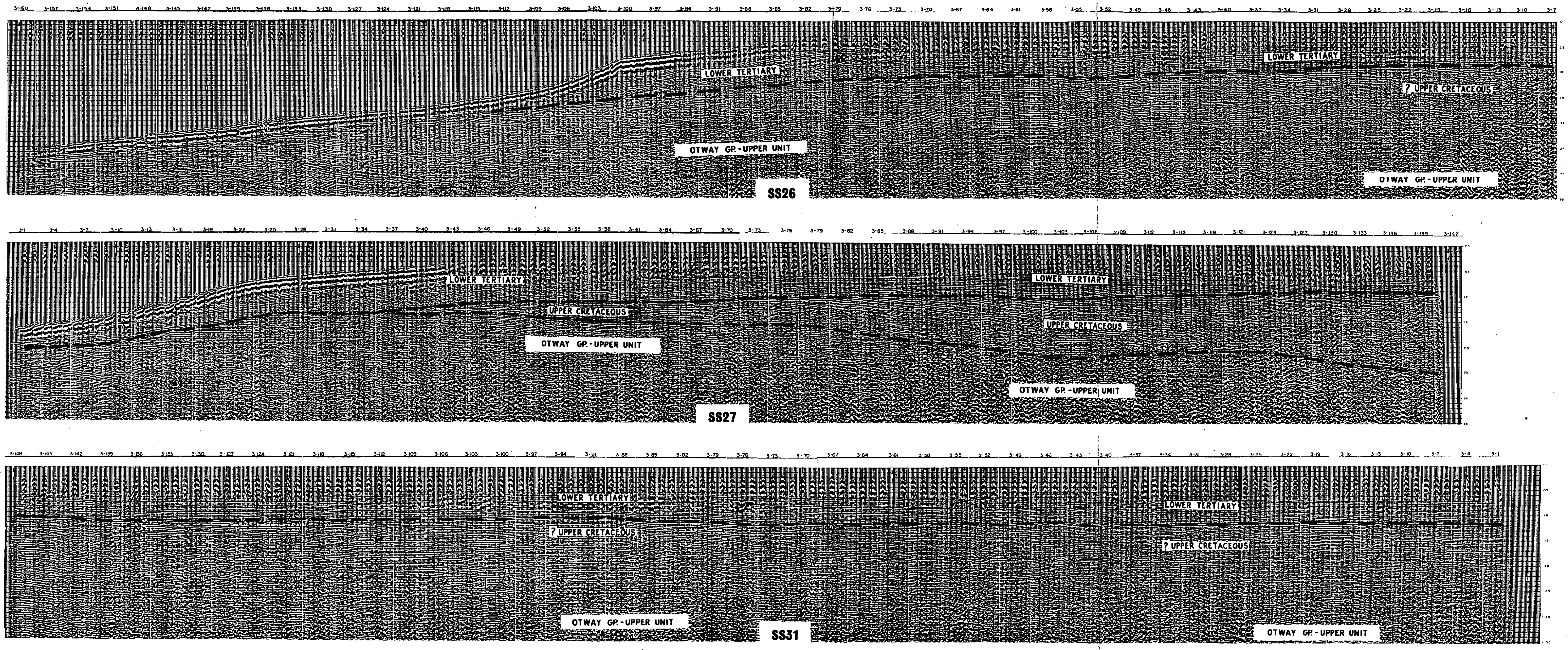


Plate 13. Geological interpretation of Haematite Explorations seismic time sections SS26, SS27, SS31.

PLATE 13

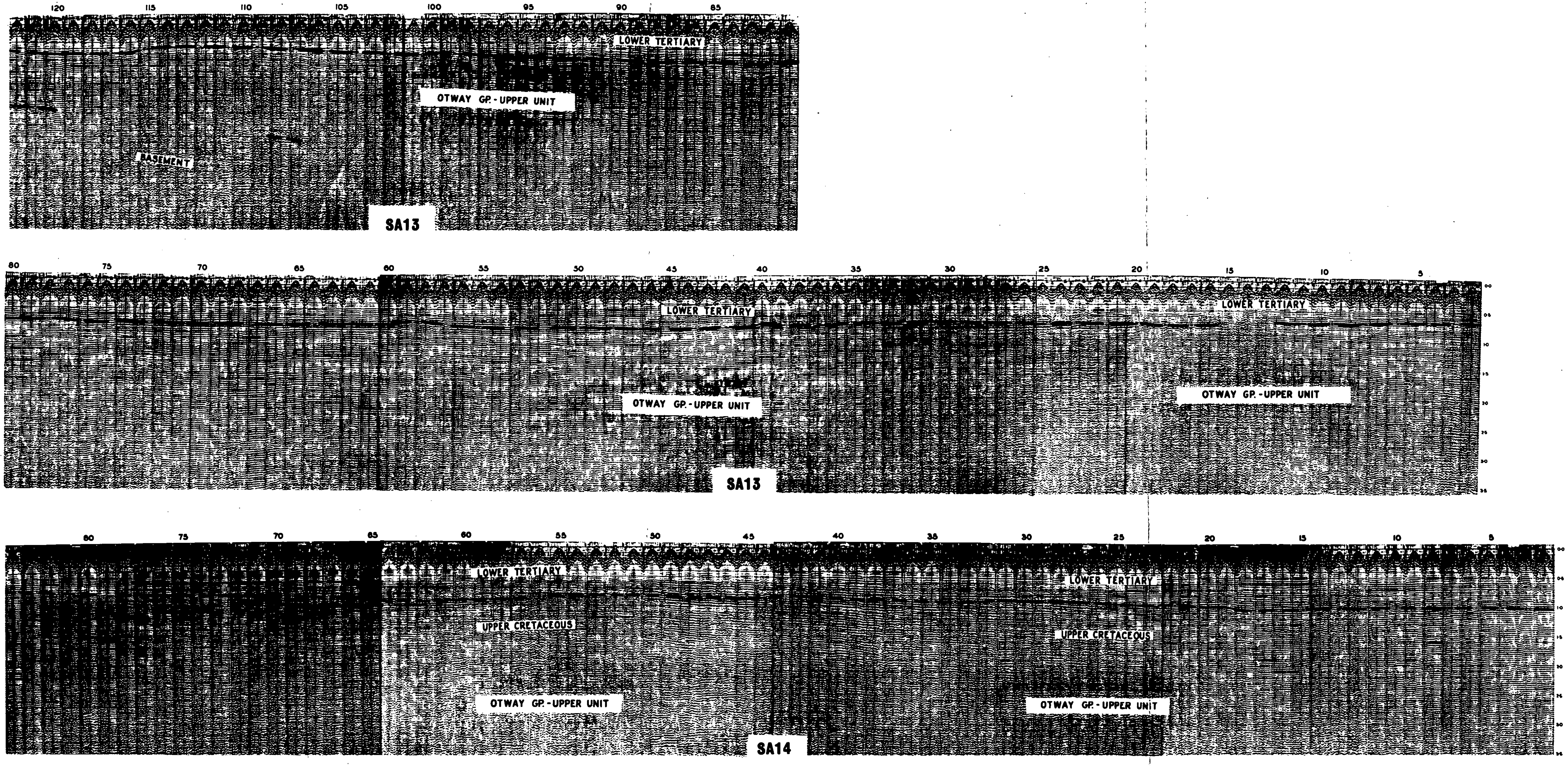
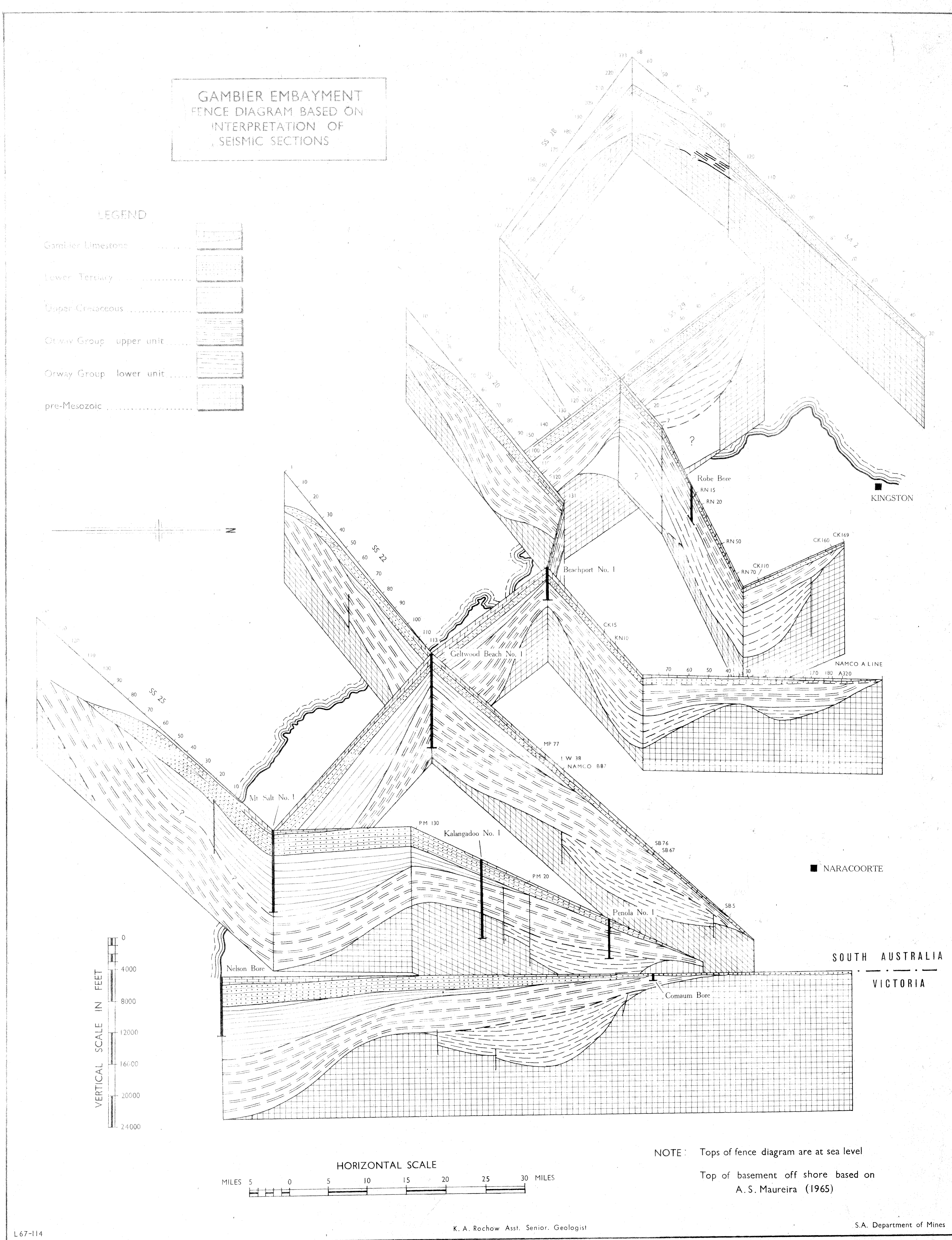


Plate 14. Geological interpretation of Haematite Explorations seismic time sections SA13, SA14.

PLATE 14



Reduce to inches

GAMBIER EMBAYMENT
FENCE DIAGRAM BASED ON OFF-SHORE
INTERPRETATION OF SEISMIC SECTIONS

F.B. L67-114/4
KCe
20-12-66

PLATE 15

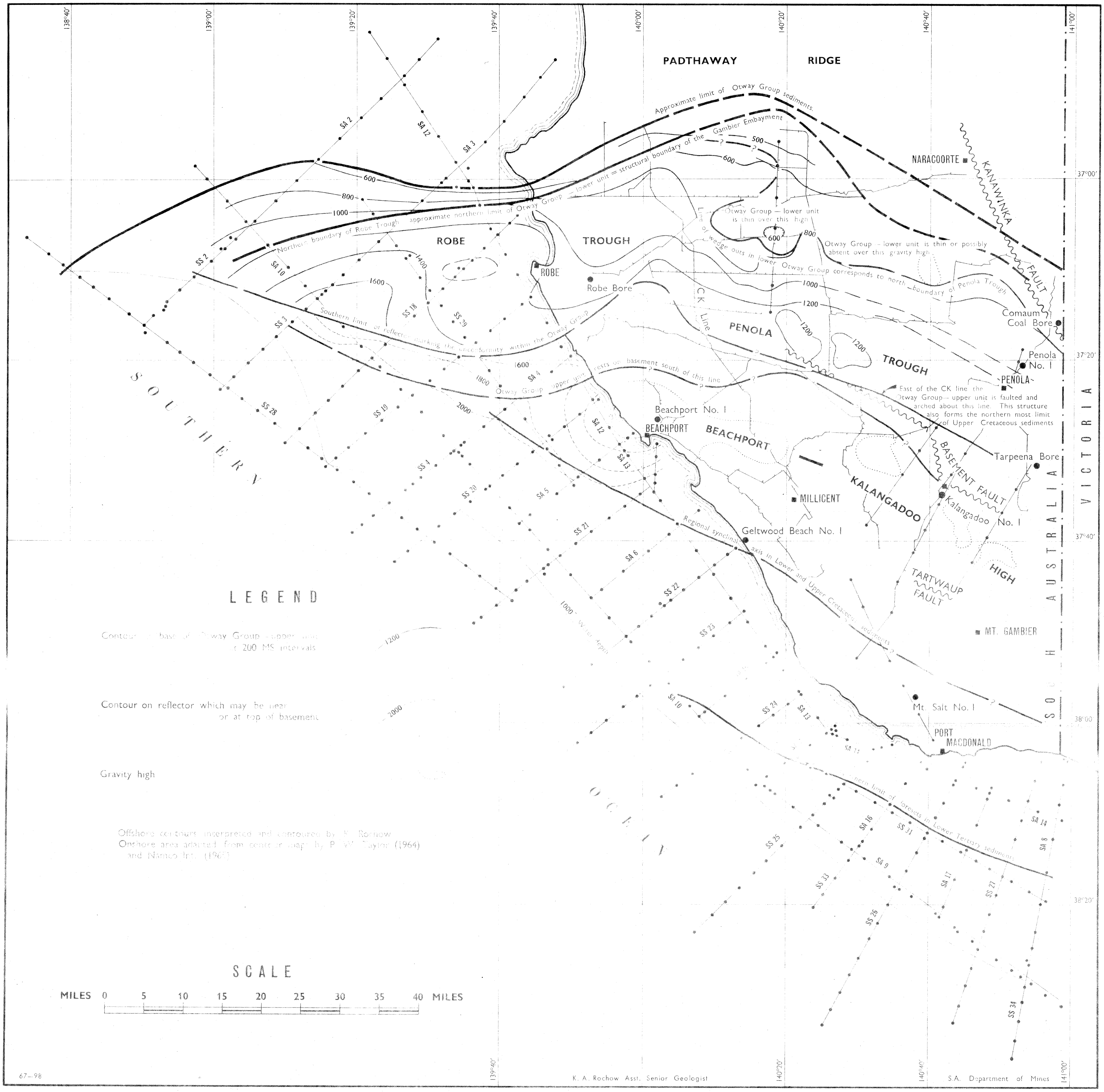
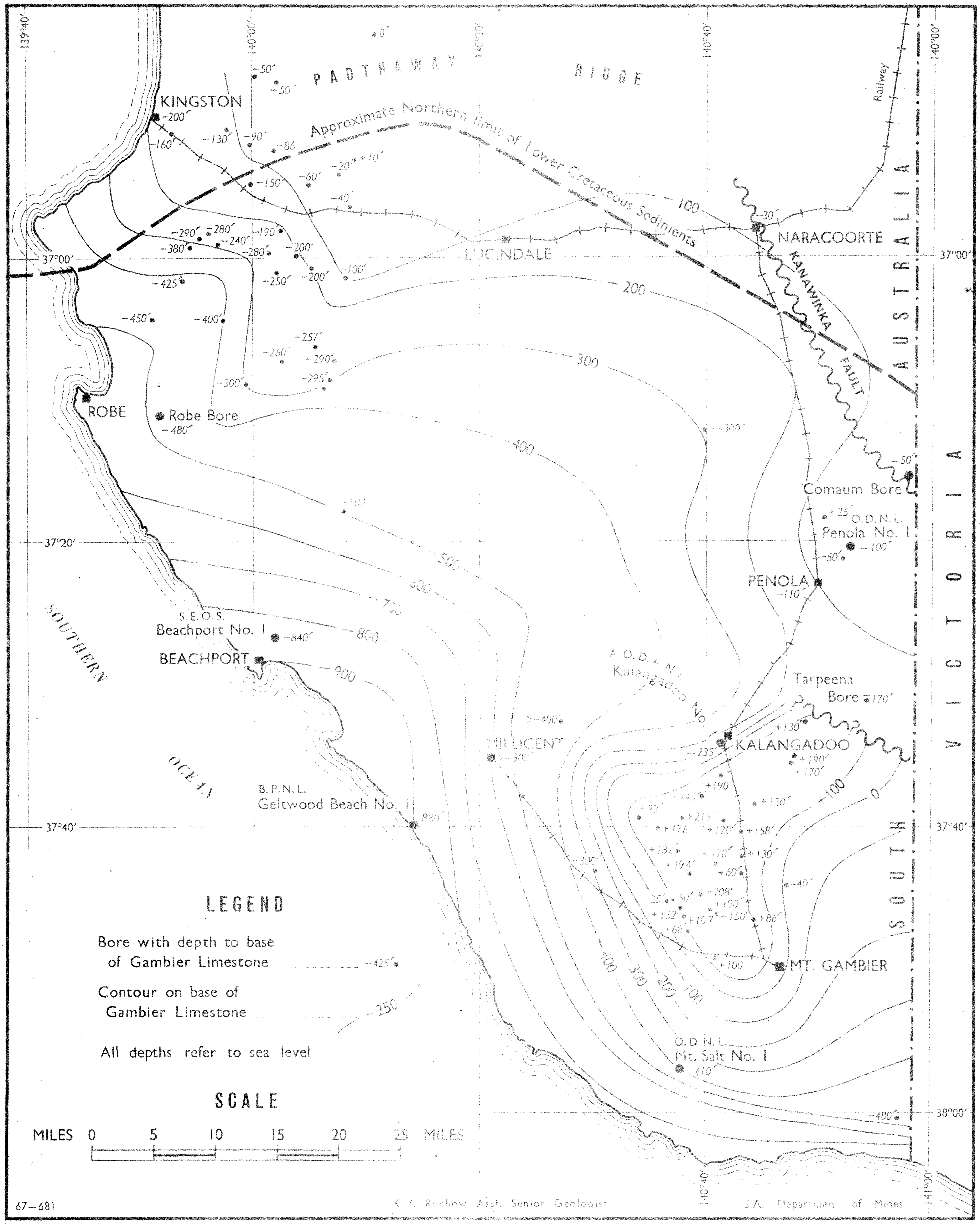


PLATE MAP SHOWING THE MAJOR STRUCTURAL FEATURES OF THE GAMBIER EMBAYMENT

PLATE 16

OTWAY B SIN

L67-98/4



Reduce to inches

PLATE CONTOUR MAP OF BASE OF GAMBIER LIMESTONE

67-681/4

PLATE 17 OTWAY BASIN

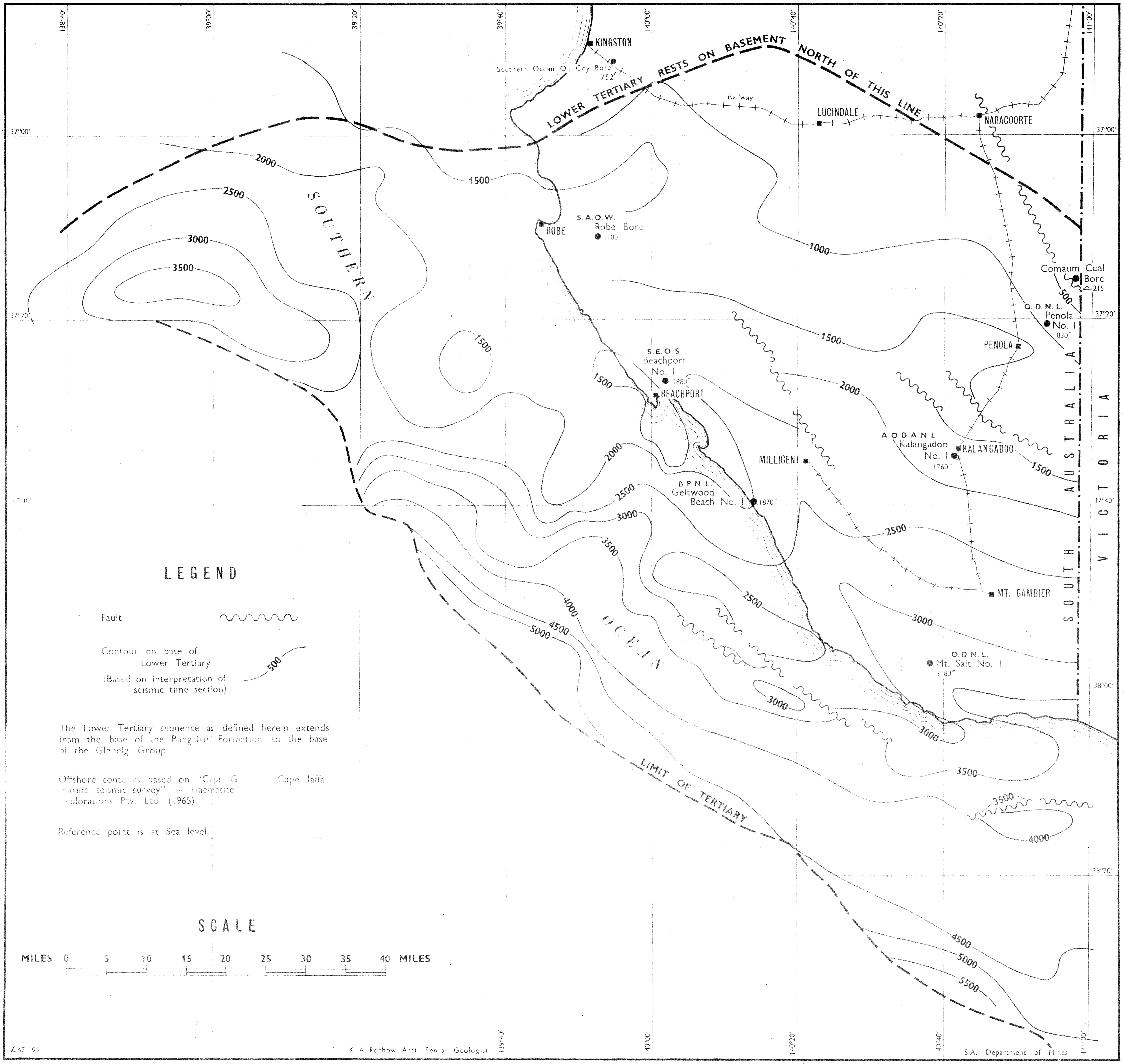


PLATE CONTOUR MAP OF BASE OF LOWER TERTIARY

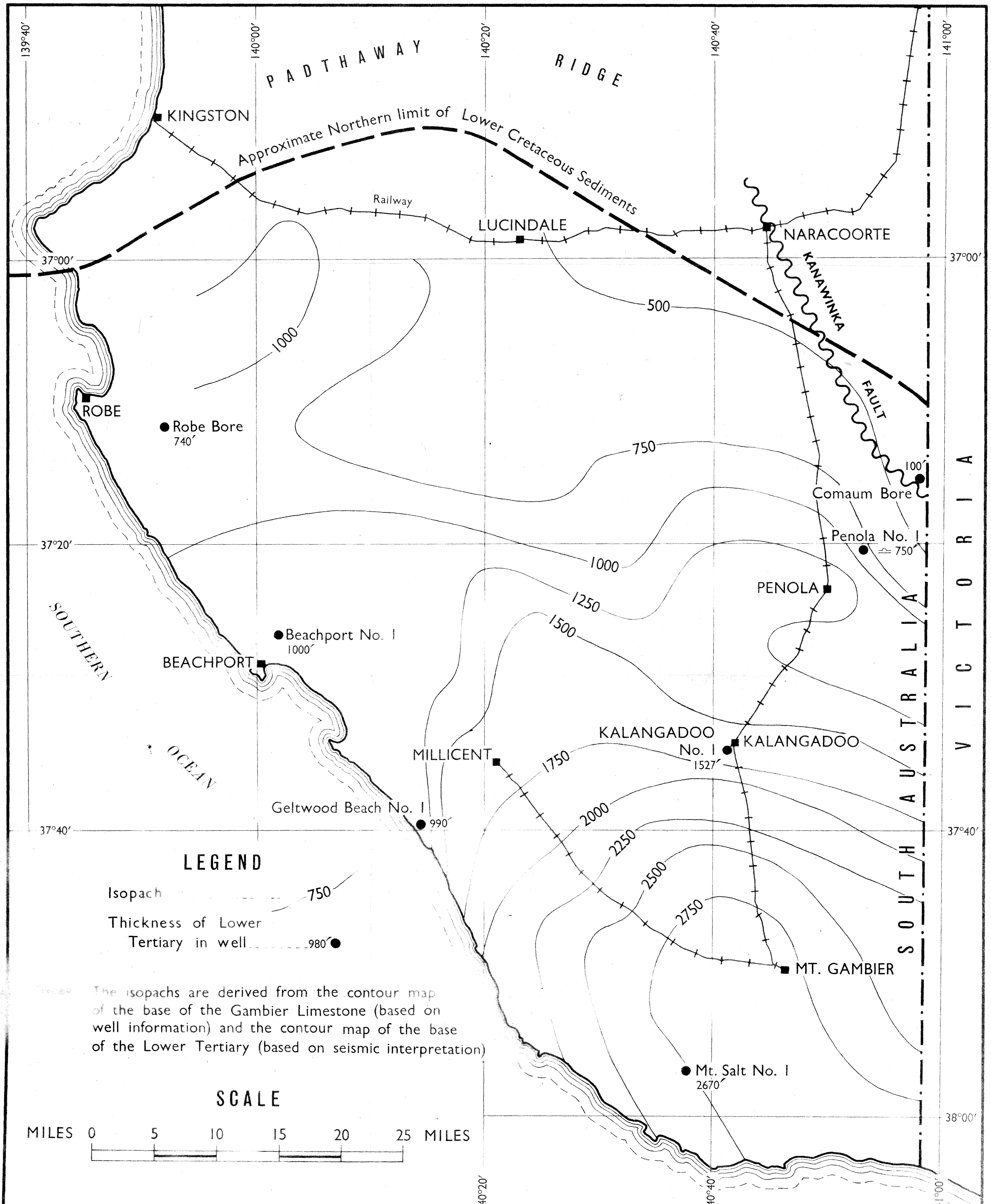
PLATE 18

PLATE 18 OTWAY BASIN

L67-99/4

Checked

Reduce to $9\frac{13}{16}$ inches



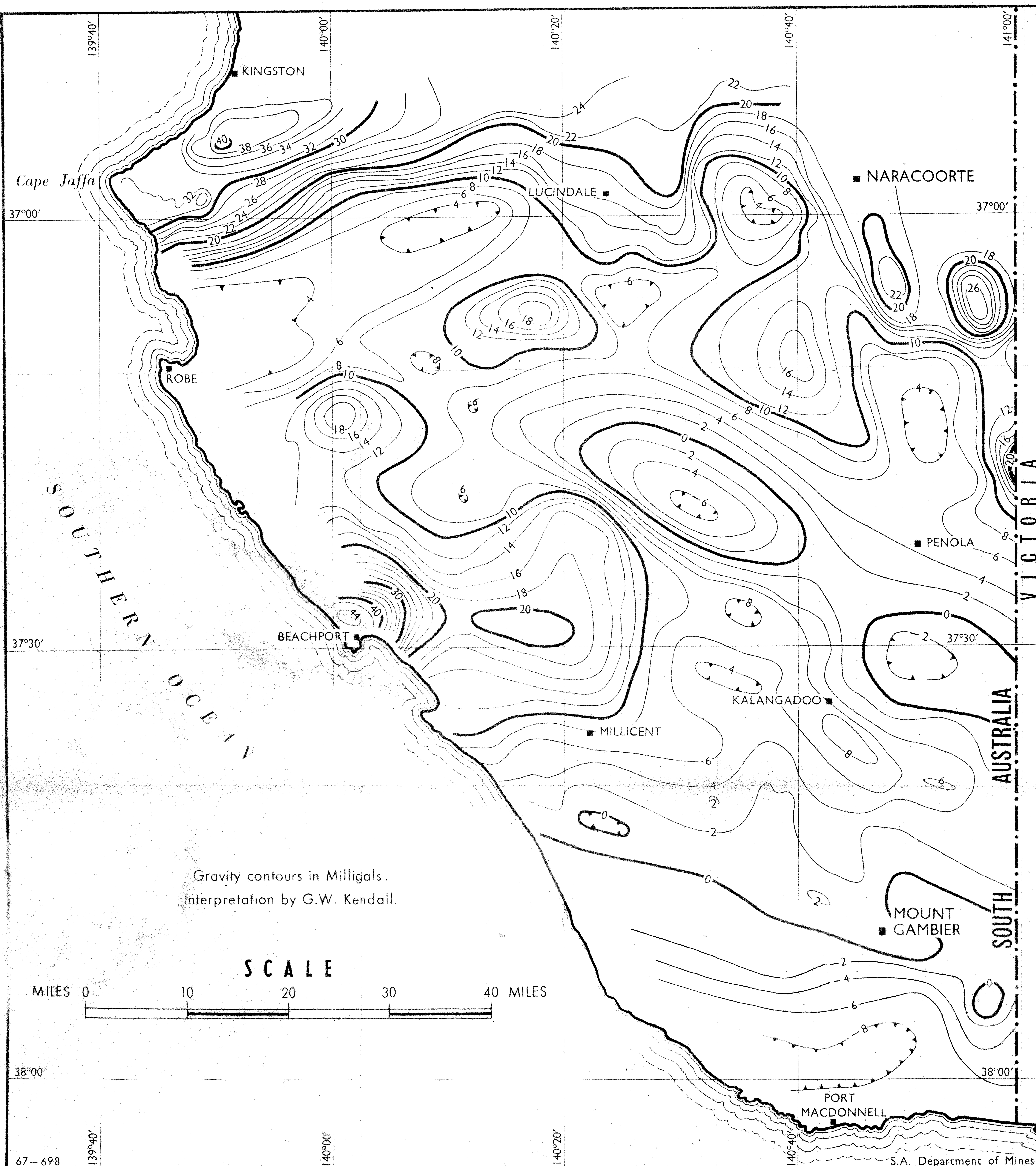
ISOPACH MAP OF LOWER TERTIARY SEDIMENTS

PLATE 19

PLATE 19 OTWAY BASIN

67-684

O.K.



RESIDUAL GRAVITY CONTOUR MAP

PLATE 20

67-698/4

Reduce to 5 1/3 inches