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PRELIMINARY ASSESSMENT OF THE HYDROCARBON PROSPECTIVITY OF AREA A OF THE ZONE OF COOPERATION

by

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Figure 12. Seismic reflection line 69-250 showing Miocene faulting at shotponts 36, 56, and 86 and flexure between shotpoints 43 and 109.

Figure 13. Geohistory of Troubadour 1 well.

## SUMMARY


Because only one explortation well has been drilled in Area A of the Zone of Cooperation, little in detail is known about its petroleum prospectivity. The results of analysis of existing regional data can be summarised as follows.

Triassic oil potential on the platform areas is possible but would represent a new play. The Triassic sequences in the central parts of the Sahul Syncline and Malita Graben, and the Permian throughout much of the region, are likely to be over mature for oil generation and would be prone to produce gas/condensate.

Jurassic petroleum source rocks similar to those in the Vulcan Graben are likely to be absent on the Sahul Platform in the region of the Kelp structure, and if present are likely to be only marginally mature. Mature oil-prone Jurassic source rocks are more likely to occur in the Sahul Trough and on the edges of the Malita Graben. However, faulting similar to that at Jabiru and Challis is present within Area A and it is possible that fault-block traps similar to those at Jabiru and Challis could be developed. Thus the best supported optimistic scenario for Jurassic oil potential is not for giant fields but for a number of small and medium fields particularly near the margins of the platform close to the regions of possible mature source rocks. The target depths for drilling are likely to be between 2000 and 3000 m (6500 and 10000 feet).

The collision of the Australian and Asian plates in the Miocene produced compression resulting in normal and reversed faults. However, the integrity of the seal associated with the Cretaceous Bathurst Island Formation was maintained as is indicated by the preservation of the Jabiru and Challis accumulations. This implies that Late Cretaceous and Tertiary reservoirs are unlikely to be charged with petroleum from Jurassic source rocks except possibly in the rare instances where large faults cut those levels. Since Cretaceous and Tertiary source rocks are immature in the region this downgrades Late Cretaceous and Tertiary prospectivity.

## INTRODUCTION

The Zone of Cooperation including Area A occurs in the north of the Bonaparte Basin (Figure 1). The Bonaparte basin occupies an approximately triangular area of 270,000 $km^2$, and contains sediments which range in age from Palaeozoic to Cainozoic. The Zone of Cooperation is situated near the northern outer edge of the basin and overlies part of several major structural features including the Sahul Platform, the Malita Graben and Sahul Syncline. The major structural elements in the basin were formed by mid to late Palaeozoic rift faulting. In the region of Area A these structures strike approximately northeast and are covered by more than 10 km of Mesozoic to Cainozoic sediments in the grabens and up to 4 km over the highs (Mory, 1988).

Petroleum industry studies of the region have been described by Warris (1973), Laws and Kraus (1974), Laws and Brown (1976), Kraus and Parker (1979), and Durrant and Young (1988), Gunn(1988a and b), Horstman (1988), Lee and Gunn (1988), MacDaniel (1988a and b), Woods (1988) and Wormald (1988). Government studies of the region have been produced by Williams and others (1973), Jones and Burgis (1974), Branson (1978), Brown (1980), Lavering and Ozimic (1988), Middleton (1988) and Mory (1988).

The prospectivity of the Zone of Cooperation can be assessed using well and seismic data from the region and, in particular, in relation to the recent small but economic discoveries of petroleum at the Jabiru and Challis fields about 200 km to the west in the Vulcan Sub-graben, the significant gas accumulations at Petrel and Tern in the south of the Bonaparte Basin, and hyrocarbon indications from other wells in the region (Figures 1 and 2).

This assessment draws on a recent preliminary analysis of Area A carried out by the Bureau of Mineral Resources, previous work by C.S. Robertson and D.J. Forman, and the many published articles on the region.

## STRATIGRAPHY

The stratigrapic units of the Bonaparte Basin have ages ranging from Precambrian to Recent (Figure 3). The oldest sediments encountered in the Northern Bonaparte Basin are Late Permian in age and indicate that a carbonate platform occupied the northern rim of the basin at that time (MacDaniel, 1988a). The Hyland Bay Formation in the northwest contains limestone fossils similar to those found on Timor, and in the northeast consists of calcilutites. Marine siltstones and shales of the Mount Goodwin Formation were deposited during the latest Permian and Early Triassic. This was overlain by the shallow marine to fluviodeltaic sediments of the Cape Londonderry Formation. These sediments consist of a mixed clastic-carbonate sequence with minor coals and volcanics. During the Early Jurassic fluviodeltaic siliciclastics of the Malita Formation were deposited. On platform areas, however, erosion of these sediments was associated with uplift which accompanied mid to Late Jurassic rifting. During the late Jurassic and Early Cretaceous, sedimentation occurred in grabens and troughs remaining after Jurassic rifting. The Flamingo Group was deposited during this time and consists of shales (Swan Formation in the Vulcan Graben and Frigate Shale over the Sahul Platform and in the Petrel Sub-basin) and sometimes undifferentiated sandstones. Shales and calcarenites of the thick (up to 2000 m) and laterally extensive Bathurst Island Group were deposited in the Cretaceous. In general the calcarenites were deposited over the more distal platforms and the shales deposited shoreward except for some sandstone deposition at the proximal margin and in the Vulcan sub-basin.

During the Paleocene to Oligocene, carbonate sediments of the Hibernia Formation retreated oceanward and were fringed landward by a thin proximal zone of siliclastic sedimentation. Shelf carbonate sediments were re-established in the Miocene with associated reef growth to the Holocene. Carbonates of this phase are unnamed regionally but are up to 1000 m thick.

## STRUCTURAL DEVELOPMENT

The Bonaparte Basin is a pie-slice shaped depression expanding outwards from its narrowest point near the shoreline. Basin development started as a result of rifting beginning in the Devonian and ceasing at mid-Carboniferous (Gunn, 1988a). The rifting phase was followed by subsidence and sedimentation.

Tectonism in the mid-Triassic produced fault trends sub-parallel to the current shelf line. Rifting again occurred along the same trend in the Mid- to Late Jurassic prior to the onset of seafloor spreading. Callovian uplift and erosion is associated with this rifting phase. The Miocene collision of the NW Australian shelf with Timor (Mory, 1988) resulted in reactivation of the Mesozoic fault systems and development of another fault system with a probable transpressional component. The later faults are sub-parallel to the Timor Trough where the collision of Australia and Timor occurred. The collision, apart from resulting in normal and reversed faulting into the shallow section, has also resulted in a flexural bulge of the continental shelf of the Bonaparte Basin adjacent to the Timor Trench. Structures of this age form traps for the Jabiru and Challis accumulations (Wormald, 1988; MacDaniel, 1988b). The structures show a cross-faulted geometry with a graben overlying a horst producing the typical 'hourglass' configuration. Studies of the structures (Woods, 1988) suggest that some of the early major faults were not reactivated and some significant collision-stage faults do not directly relate to older faults (Fig. 4). Faulting of the type associated with the Jabiru and Challis accumulations is present in the Zone of Co-operation.

## POTENTIAL RESERVOIR ROCKS

Regionally, sandstones with petroleum reservoir potential occur in the Upper Permian, Middle-Upper Triassic, Middle-Upper Jurassic and the Upper Cretaceous. Reservoir quality varies due to syndepositional and post depositional changes.

Potential reservoirs of Permian age include the Upper Permian Hyland Bay Formation sealed by the overlying thick shales of the Lower Triassic Mount Goodwin Formation, and are likely to be shallow enough to warrant consideration as a possible exploration drilling target only around the flanks of the Sahul Platform and Darwin Shelf.

Triassic reservoirs within Area A consist of a marine shelf carbonate sequence on the Sahul Platform, as outlined by Mory (1988). The carbonate sequence passes south and westwards into the Londonderry Formation both in the Malita Graben and Sahul Syncline, where respectively mixed clastic and carbonate sequences were deposited. On the southern margin of the Malita Graben and southwards into the Petrel Triassic sub-basin, fluvial clastic sediments were deposited behind a narrow barrier/strand line sequence. Along much of the Darwin Shelf clastic and volcanic sediments of similar age have been deposited.

From Late Triassic to Early Jurassic a marine regression deposited a red-bed sequence over Area A. This was succeeded by fluviodeltaic sediments of the lower Petrel Formation which were deposited in the northern Petrel Sub-basin and part of the Sahul Platform. This sequence passed offshore into marine shelf shales in the Sahul Syncline and the western part of the Malita Graben.

In addition to the strata encountered in wells in the region, there is possible development of carbonate reefs in the Upper Triassic providing a possible additional exploration play (Williamson and others, 1989). Site 764 of the Ocean Drilling Program (ODP), drilled during Leg 122 in the Exmouth Plateau region to the south, cored 200 m of Upper Triassic (Rhaetian) reef complex. This site, on the northern Wombat Plateau (northernmost Exmouth Plateau) represented the first discovery of Triassic reefal material near the Australian North West Shelf.

Application of the seismic criteria for reef recognition established at ODP Site 764, to other seismic reflection data on the Wombat Plateau, demonstrated that a major Upper Triassic reef complex fringes the margins of the Wombat Plateau. The Wombat Plateau lies at the western end of the North West Shelf, which was part of the southern margin of a warm Tethys Ocean in the Late Triassic, at a palaeolatitude of 25-30$^{o}$S. Upper Triassic carbonate complexes are also known to occur in Timor. They may be common along the outer margin of the North West Shelf including the Bonaparte Basin where they could occur on the continental shelf (Fig. 5).

Middle and Late Jurassic erosion removed some of the earlier sequence from the higher parts of the Sahul Platform and other similar elements such as the Ashmore Block.

The late Jurassic to Early Cretaceous upper Petrel Formation was deposited as marine shelf shales and sands with some landward deltaic sequences (Mory 1988). This sequence forms reservoirs for some of the major petroleum accumulations on the Londonderry High and Vulcan Sub-basin, where late Middle Jurassic-Lower Cretaceous sandstones within the Petrel Formation are sealed by overlying shales of the thick and widespread Bathurst Island Formation which provides a regional seal for all potential Jurassic accumulations. The sequence beneath the regional seal is likely to be a major exploration target for drilling in Area A.

While minor petroleum indications are evident from reservoirs in the Cretaceous and Tertiary sequences, nearby well results clearly indicate that these sequences are immature for petroleum generation. While the quality of potential clastic reservoirs in this part of the sequence may be highly favourable, they are not expected to be locations of major petroleum accumulations.

## PETROLEUM SOURCE ROCKS

Carboniferous rocks are the likely source of gas discovered in the Bonaparte 2 well, and are a possible source for the gas encountered in the Petrel and Tern gas accumulations in the Petrel Sub-basin, south of Area A. The Lower Permian section in that area is moderately rich in organic carbon (Kraus and Parker, 1979). Upper Permian sediments (Hyland Bay Formation) deposited in the Petrel Sub-basin and on a large part of the Londonderry High to the west of Area A also show good source rock potential, particularly for gas, but probably also for some oil. Permian sediments are mature or over-mature for hydrocarbon generation over most of Area A.

The source-rock potential of Triassic to Lower Jurassic strata is less well known but probably is fair. These sediments exhibit moderately good potential over the Londonderry High and the western part of the Sahul Syncline. The Middle Jurassic to Neocomian sequence in Area A is expected to have source-rock potential ranging from poor to good. Jurassic rocks may have marginal to good source-rock characteristics in the Malita Graben and Sahul Syncline areas but good source-rock potential is prevalent in the central parts of the grabens, where preservation of large quantities of organic carbon is due to a relatively high rate of sedimentation in the rapidly subsiding Jurassic depocentres. Shales in the lower levels of the Jurassic Petrel Formation are probably capable of generating both oil and gas. Jurassic sediments tend to be early mature to mature for hydrocarbon generation in the Jurassic depocentres and only in Heron 1 near the axis of the Malita Graben are they possibly over-mature.

Cretaceous sediments of the Bathurst Island Group are generally organically lean (carbon content of less than 1 percent) although higher values are evident in the northern part of the Petrel Sub-basin, south of Area A, in the Malita Graben, and on the northern part of the Londonderry High. The sediments are generally early mature to post-mature in the Malita Graben, but elsewhere range from immature to early mature. Overall, the Bathurst Island Group has some potential for generation of both oil and gas and is best in the areas with higher organic carbon and maturity values.

Tertiary sediments do not approach maturity in the Bonaparte Basin (or in Area A) and are therefore not a major potential hydrocarbon source.

## PETROLEUM ACCUMULATIONS

The locations and stratigraphic levels of hydrocarbons encountered in the Bonaparte basin are summarised in Figures 1 and 6. The first significant hydrocarbon discovery in the Bonaparte Basin was in 1969 when the Petrel 1 well struck gas. The largest measured flow from the structure was in Petrel 3, which flowed at up to 2,043,900 $m^3$ of gas per day. By comparison, nearby Tern 1 (1971) produced 706,000 $m^3$ of gas per day while Tern 2 (1982) flowed at up to 1,384,300 $m^3$ of gas per day. The two fields have reserves of approximately 300 and 45 billion cubic metres, respectively. The Tern wells have been suspended. The next gas discoveries were Troubadour 1 and Sunrise 1 which were drilled in 1974-5 on the Sahul Platform. The former well also produced condensate at 35.7 kl per day (225 BPD).

In 1972 the first significant oil discovery in the basin, Puffin 2, flowed at up to 730 kl per day (4608 BOPD) but this flow rate was not sustained. Subsequent oil discoveries have been made, in the west of the basin, in the region of Ashmore and Cartier Islands. The first, in 1983, was Jabiru 1A which recorded a maximum unstabilised flow of 1190 kl per day (7500 BOPD). Production from the field commenced in 1986 at 2100 kl per day (13200 BOPD) from Jabiru 1A and increased to approximately 4770 kl per day (30000 BOPD) after the drilling of Jabiru 5A. To date, seven wells have been drilled in this field. Reserves are estimated at 7,630,000 kl (48 million barrels) of recoverable oil. Other discoveries include the Challis field in 1984 with reserves estimated at 3,500,000 kl (22 million barrels) of recoverable oil, Skua 3 which flowed at up to 810 kl per day (5096 BOPD) in 1985, and Oliver 1 in 1988.

## DATA QUALITY

In the Bonaparte Basin early seismic data failed to delineate Jurassic and deeper events because of the complex seismic response of the overlying geological section, and the complications arising from water bottom irregularities (Durrant and Young, 1988). Base Cretaceous was the deepest seismic horizon interpreted with any confidence and this militated against good seismic definition of potential trapping structures. State-of-the-art source and streamer technology has improved data quality greatly in the broader region and has underpinned recent exploration successes.

In Area A, however, all existing seismic data is more than 15 years old and is not well suited to definition of the type of trapping structures which are producing oil at Jabiru and Challis. In addition the seismic data grid in Area A is sparse and, commonly, could not define structures of this type because of insufficient line density.

In this preliminary analysis these data have been used for definition of gross structure in part of Area A and to indicate structural style. Modern high-quality data are needed for a more adequate evaluation.

## ANALYSIS OF DATA

### Seismic Interpretation

To provide insights into structural and stratigraphic development of Area A, and in particular the effect on the region of the collision with Timor, a preliminary seismic interpretation exercise was carried out over a region near the edge of the continental shelf of the western Sahul Platform and corresponding to the crest of the Kelp structure. The location is shown in Figure 7. The region encompasses water depths from less than 50 m corresponding to local reefs to over 400 m. To try to achieve valid structural mapping, depth conversion of the time structure maps was carried out using interval velocities between horizons obtained from the Troubadour 1 well.

Seismic horizons were tied to the Troubadour 1 well on the eastern Sahul Platform. Horizons at Miocene, Paleocene, Jurassic, Triassic, Permian and basement levels were interpreted over an area of 5000 sq. km using 1100 km of multichannel seismic reflection data collected in 1969 and 1970 for BOC. Depth conversion of the time horizons was necessary because of the variations in the water depth associated with the upper continental slope and due to reefal development.

The detailed analysis of the seismic data grid indicates three main phases of generation of structure. These are Palaeozoic rifting, Mesozoic rifting and Miocene structures associated with the collision with Timor. Both the Mesozoic and Miocene rifting events reactivated older faults as well as generating new faults which cut deeper levels. The Palaeozoic and Mesozoic rifting was associated with normal faulting. The dominant structural configuration at top Jurassic level is associated with Mesozoic rifting. The Miocene collision event produced normal and reversed faults and the presence of flower structures indicates a wrench component. The older dominant structural configuration at top Jurassic has been modified by lesser Miocene faulting and flexure associate with the collision event.

The Kelp structure has an area under closure of approximately 7000 sq. km. The depth structure map at top Triassic level over the crest of the Kelp structure (Fig. 8) reveals, apart from the culmination of the Kelp structure which dominates the centre of the mapped area, four secondary closures with areas in the order of 10-30 sq. km and vertical closures up to 150 m, at depths between 2600 and 3000 m (8500 and 10000 feet). These structures are poorly defined by the present data grid and velocity control, but are believed to be indicative of the type of structure which could become targets for hydrocarbon exploration in the region, assuming the Kelp structure achieves only a low level of fill.

At the more prospective top Jurassic level, secondary structures with areas in the same range as those at top Triassic level are observed (Fig. 9). There are seven of these in the mapped area. Vertical closures are in the order of 50 m at depths between 2000 and 2200 m (6500 and 7200 feet) and do not, except in two cases, correspond with closures on the top Triassic surface. Some of the structural closures are fault dependent and rely on faulting like that associated with Jabiru and Challis and some are anticlinal. The main culmination of the Kelp structure at top Jurassic is affected by the Miocene flexure and is expressed in the mapped region as two closures with areas in the order of 250-300 sq. km and vertical closures of around 60 m. Again, seismic line density and poor velocity control do not allow good definition of these structures. It is considered, however, that these and similar structures will be the main focus of exploration assuming the Kelp structure achieves low fill and migration is from the troughs near the margins of the structure, where mature Jurassic oil source rocks could be present.

Four closures with areas between 10 and 50 sq. km and vertical closures in the order of 50 m are mapped at the Paleocene horizon at depths of approximately 1550 m (5100 feet; Fig. 10). No closure corresponds to the top of the Kelp structure at this level. Two of the closures are associated with Miocene faulting which produces throws of up to 75 m along the hinge line at the edge of the continental shelf. This latter type of structure probably represents the only chance of Tertiary oil accumulations in the region, and would require that oil from deeper, problably Jurassic, source rocks migrate to the region and up the fault zones.

Two seismic examples (Figures 11 and 12) are included to show the structural style of the mapped area. Line 70-449 (Fig. 11) shows the dominant Palaeozoic and Mesozoic faults at the south of the line. Note how the throws of the faults in that area are greatest at top basement and have decreased to almost zero at the Paleocene horizon. The effects of faulting associated with the Miocene collision with Timor can be seen at the north of the line. The faults at shotpoints 86 and 56 reactivated older faults whereas the fault at shotpoint 36 does not appear to have done so. The faults terminate at the prominent Miocene unconformity. Line 69-250 (Fig. 12) shows the Miocene flexure associated with the collision. Flexure is centred around shotpoint 70 and extends between shotpoints 43 and 109.

### Geohistory Analysis

A geohistory analysis of the location of the Troubadour 1 well was carried out to investigate the burial and maturation history of the source rocks in the region (Fig. 13). The geohistory method allows for decompaction of strata as overlying -layers are progressively removed, the degree of decompaction depending on rock type. Maturity for petroleum generation in terms of Vitrinite Reflectance Coefficient (Vo) was calculated within the program and compared with values derived from the well. The Jurassic oil source rock in the region is expected to be predominantly humic in nature. Consequently, generation of oil would begin by around 0.7 percent vitrinite reflectance. This corresponds to a depth of 2.2 km (7200 feet) in the Troubadour 1 well.

## REGIONAL PETROLEUM PROSPECTIVITY

Although little is known in detail about the petroleum prospectivity of the Zone of Cooperation, including Area A, some general points can be made.

The most significant hydrocarbon discoveries with respect to the Zone of Cooperation and Area A have been oil at Jabiru, Challis, Skua and Puffin, and gas and condensate at Swan in the Vulcan Sub-basin and Londonderry High areas; and gas at Petrel and Tern in the Petrel Sub-basin. Other significant but smaller discoveries close to Area A include the Troubadour and Sunrise gas/condensate accumulations on the Sahul Platform. From these discoveries (Appendix 1) it is possible to suggest the likely size and nature of potential hydrocarbon accumulations within the Zone of

Cooperation and Area A.

The Jabiru 1A well encountered a significant accumulation of oil near the top of the Lower to Middle Jurassic sequence. Minor hydrocarbon indications were observed in the Cretaceous and Triassic sequences. The oil accumulations discovered at Jabiru and Challis are present in traps developed by marine shale of the Cretaceous Bathurst Island Group overlying and sealing Jurassic fault block traps containing highly-faulted Jurassic and Triassic reservoir sandstones. A common characteristic of these and other petroleum accumulations discovered in the Vulcan/Londonderry areas is that the petroleum and minor gas are present as relatively thin columns within highly faulted traps. The major source rocks for these accumulations appear to be the Middle Jurassic shales which are thermally mature in the Vulcan Sub-basin.

In Area A, fault-dependent and faulted anticlinal structures of relatively low vertical relief have been mapped at top Jurassic and top Triassic levels in the region of the crest of the Kelp structure. Jurassic petroleum source rocks similar to those in the Vulcan Graben are unlikely to be present in the region of the structures, however, and if present are likely to be only marginally mature. Both the marginal maturity of any Late Jurassic petroleum source rocks present and the likely necessity to migrate oil from trough or graben areas to the structures, suggest a low level of fill of the main Kelp structure and argue against the presence of giant oil fields. However, faulting similar to that at Jabiru and Challis is present within Area A and it is possible that similar fault-block traps could be developed. The best supported optimistic scenario for Jurassic oil potential is for a number of small to medium fields particularly near the margins of the platforms and adjacent to mature source rocks in the troughs. Target depths for drilling are expected to be between 2000 to 3000 m (6500 to 10000 feet).

Triassic oil potential on the platform areas is possible but would represent a new play. Williamson and others (1989) have demonstrated the possibility of a platform carbonate related Triassic oil play in the broader region but its presence has not been demonstrated. The Triassic sequences in the central parts and margins of the Sahul Syncline and Malita Graben, and the Permian throughout much of the region, are likely to be over mature for oil generation and would be prone to produce gas.

The collision of the Australian and Asian plates in the Miocene produced compression resulting in normal and reversed faults and flexure in the region. This faulting and flexure enhanced closure of second order structural highs on the top of the Kelp structure at the top Triassic seismic horizon and may be responsible for forming a number of the the second order closures at the top Jurassic seismic horizon. The faulting also formed a number of Tertiary fault-bounded structures in the north of Area A. The Miocene faults may have been important in providing migration paths for hydrocarbons. The integrity of the seal associated with the Cretaceous Bathurst Island Formation is indicated, however, by the preservation of the Jabiru and Challis accumulations. This implies that Late Cretaceous and Tertiary reservoirs are unlikely to be charged with petroleum from Jurassic source rocks in the Zone of Cooperation and in Area A unless large faults cut those levels. Since Cretaceous and Tertiary source rocks are immature in the region this downgrades Late Cretaceous and Tertiary prospectivity.

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## APPENDIX 1: PREVIOUS DRILLING

Ten wells have been drilled around Area A but only one, Flamingo No. 1, within Area A.

| Well | Year Drilled | Operator | Total Depth (m) | Bottomed in | Hydrocarbon Indications |
|---|---|---|---|---|---|
| Gull No. 1 | 1971 | ARCO | 3421 | Triassic | None |
| Flamingo No. 1 | " | " | 3700 | Jurassic | Minor Jurrasic gas shows |
| Plover No. 1 | 1972 | " | 2438 | Permian | Minor Permian gas show |
| Plover No. 2 | 1974 | " | 1524 | " | Minor Permian gas show |
| Plover No. 3 | 1977 | " | 1219 | " | Minor Permian gas show |
| Shearwater No. 1 | 1974 | " | 3178 | Jurassic | Jurassic oil staining fluorescence |
| Troubadour No. 1 | " | BOC | 3459 | Permian? | Late Mid-Jurassic gas accumulation |
| Sunrise No. 1 | 1975 | " | 2341 | Jurassic | Late Mid-Jurassic gas accumulation |
| Curlew No. 1 | " | ARCO | 2035 | " | None |
| Darwinia No. 1 | 1985 | WMC | 2426 | " | Cretaceous gas shows |
| Jacaranda No. 1 | 1984 | " | 3783 | " | None |
| Heron No. 1 | 1972 | ARCO | 4209 | " | " |

Gull No. 1 was drilled on a structure believed to have been influenced by a postulated salt diapir at depth, although the well did not penetrate to the supposed salt intrusion. The main target was Jurassic which had low porosities. Some samples from the Petrel Formation showed good oil source potential, but the hole was dry.

Flamingo No. 1 was drilled on a small lobe near the western margin of a very large, low-relief structure. No significant hydrocarbon shows were encountered above 1857 m, but from this depth onwards several poor to good gas shows were recorded. There is a small gas column of several metres thick in the Jurassic but permeability is low. A small amount of crude oil was recovered from a core from the Upper Jurassic.

Plover Nos. 1, 2, 3 were drilled near the basin margin. Although all three wells were dry, source rock analyses demonstrate high total organic carbon in the Permian Hyland Bay Formation, which is believed to have some oil-generating potential at this location.

Shearwater No. 1 was drilled on an elongate northeast-trending horst on the southern edge of the Sahul Platform just to the north of the Malita Graben. The well penetrated a section ranging from Tertiary to Middle Jurassic. No sandstones were encountered in the Cretaceous section, and secondary silicification in Jurassic sandstones downgraded porosity and permeability.

Troubadour No. 1 and Sunrise No. 1 were drilled about 16 km apart on separate culminations of the Troubadour (or Sunrise-Troubadour) dome. Normal faulting has occurred extensively throughout the area and trends towards the northeast and east-northeast.

Troubadour No. 1 drilled hydrocarbon shows in Jurassic sandstones sealed by overlying Upper Cretaceous claystones. The recovery of oil from a core and the testing of 9.86 MMcf/d of gas from sandstone intervals has demonstrated the high likelihood of hydrocarbon accumulations of this type on the Sahul Block. The well was suspended as a gas/condensate discovery.

Sunrise No.1 encountered a similar stratigraphic section to Troubadour No.1, but terminated in Middle Jurassic sediments. Hydrocarbon shows were encountered in Upper Jurassic sandstones and the well was suspended as a gas/condensate discovery.

Curlew No. 1 was an unsuccessful well on a structure influenced by a probably salt diapir at depth. The well encountered Jurassic with porosities ranging from about 19 percent near the top to about 13 percent near total depth. The less well cemented beds show good reservoir characteristics.

Heron No. 1 was drilled near the axis of the Malita Graben. Below a normal thickness of Tertiary sediments the well penetrated a very thick section of Lower Cretaceous and Upper Jurassic shales. Porosity in thin sandstone stringers penetrated in the Jurassic was very poor. Samples from the Upper Jurassic showed high total organic carbon content, but because of an unusually high geothermal gradient of 4.75°C/100 m, the Jurassic section is probably post-mature for oil generation. The Upper Cretaceous, which is generally immature elsewhere, is mature at least in part at Heron, but lacks good reservoirs.

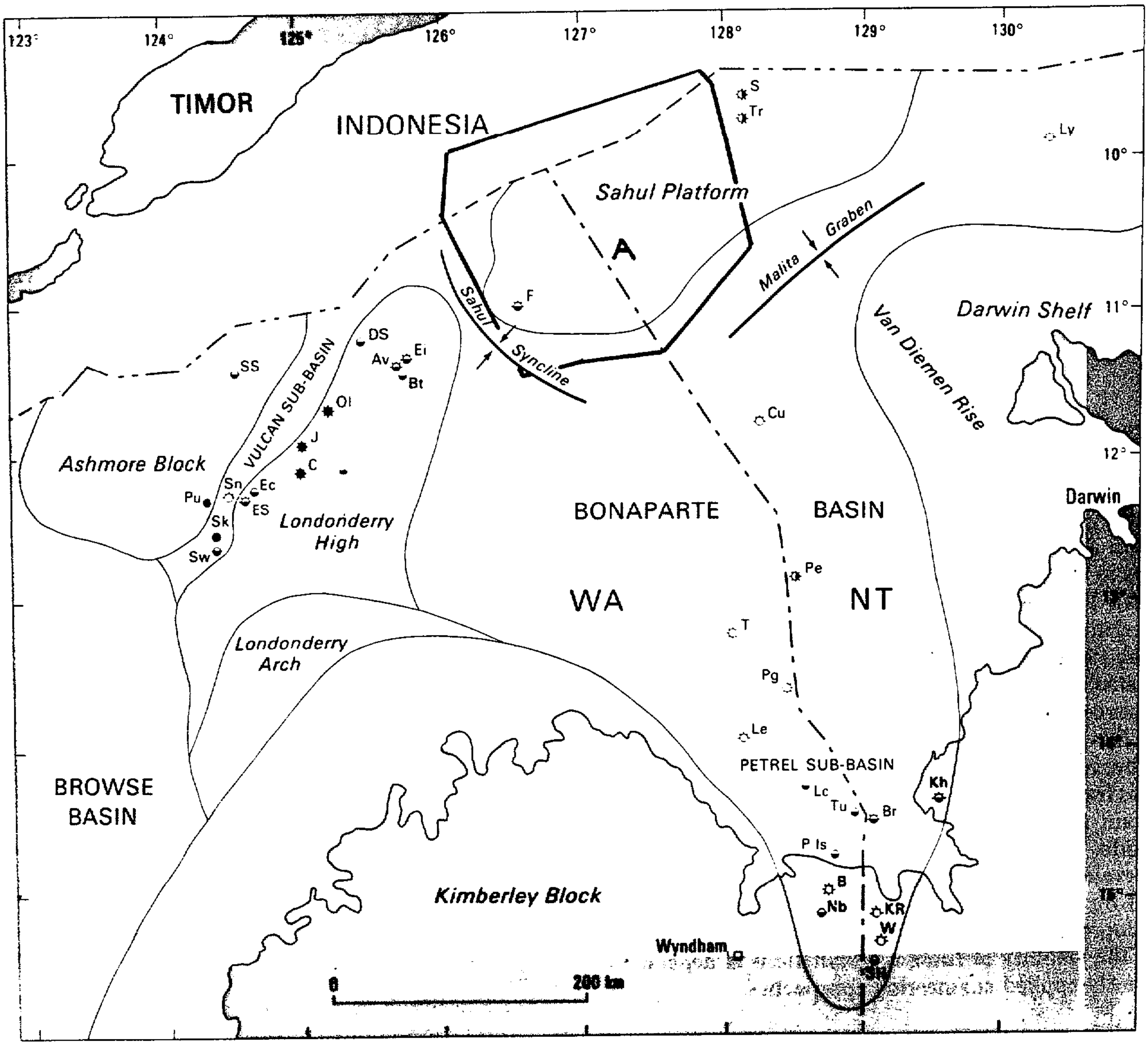


Figure 1. Location map of structural elements and petroleum accumulations of the Bonaparte Basin showing Area A of the Zone of Cooperation. Abbreviations for well names are given in Figure 6.

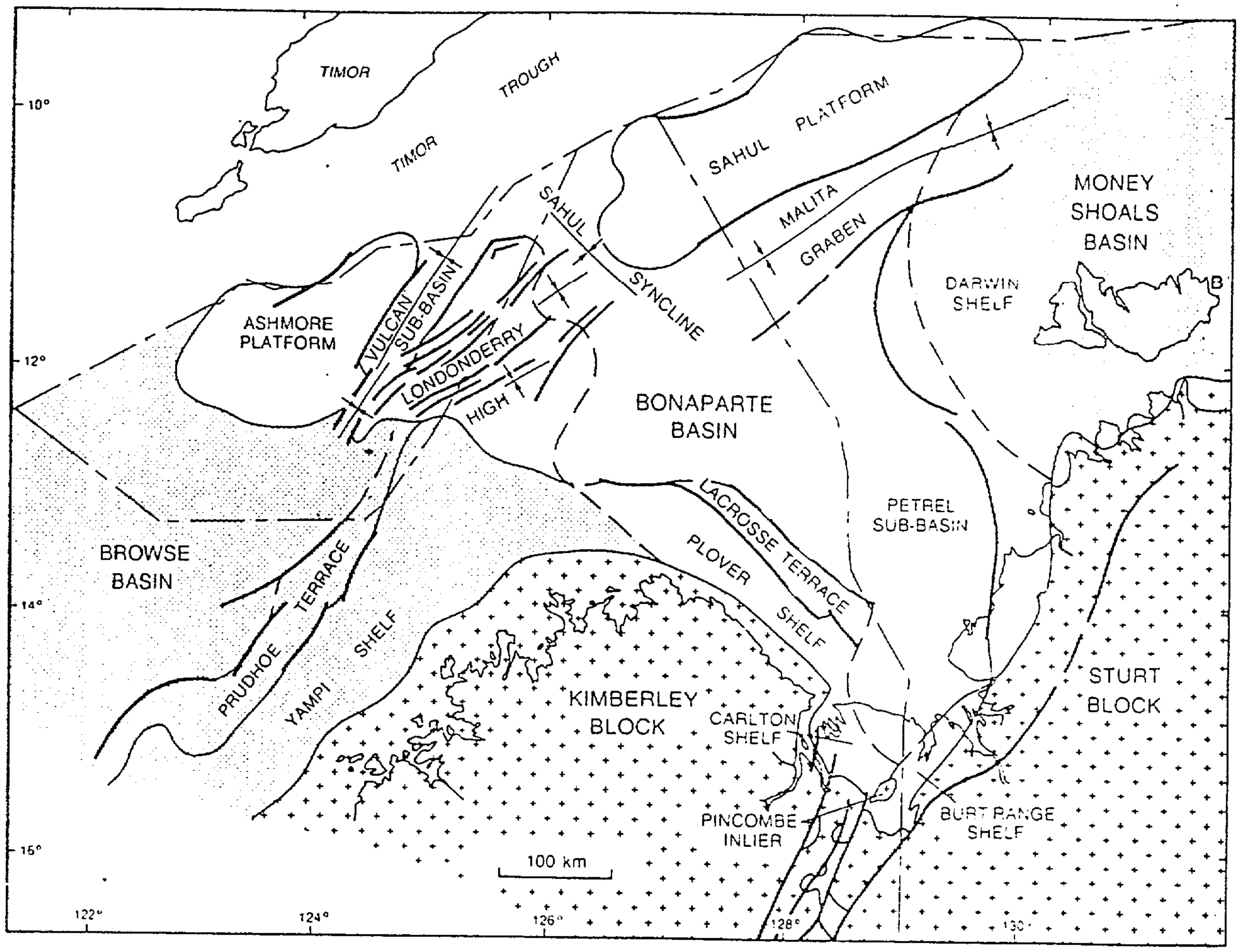


Figure 2. Structural subdivisions of the Bonaparte Basin (modified after Bhatia and others, 1984).

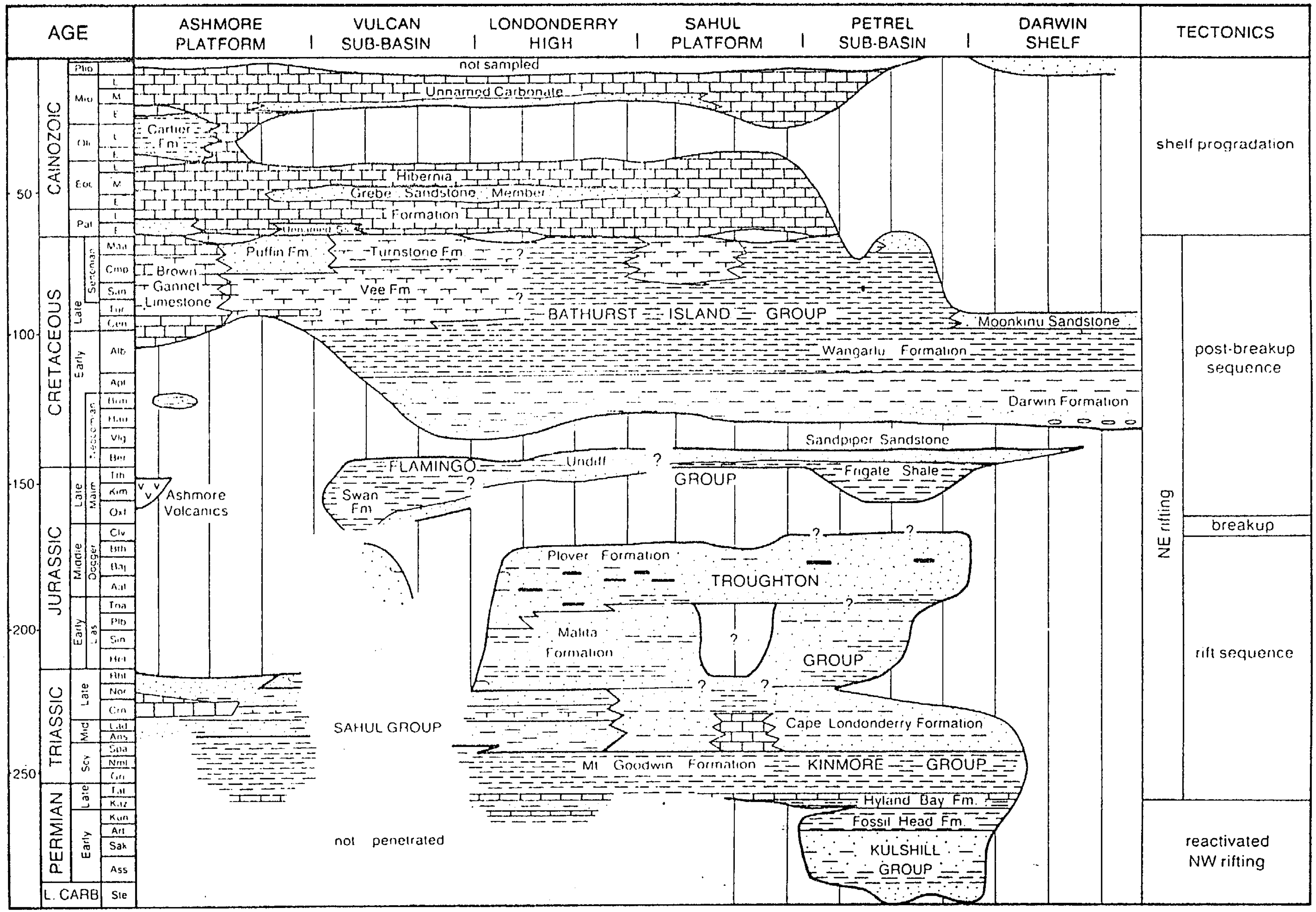


Figure 3. Permian to Cainozoic stratigraphy and tectonics ( after Mory, 1988).

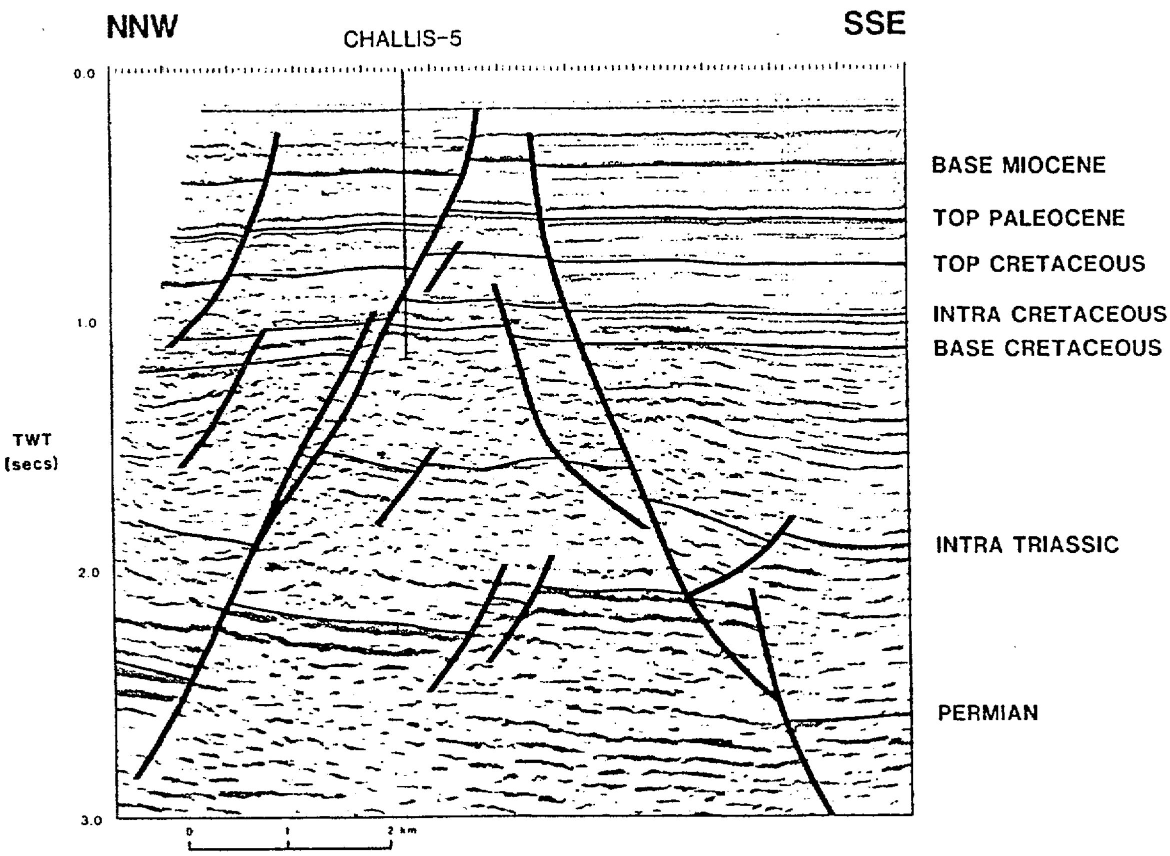


Figure 4. Seismic reflection line CH-37 through the Challis-5 location (after Wormald, 1988) showing faulting characteristic of the region.

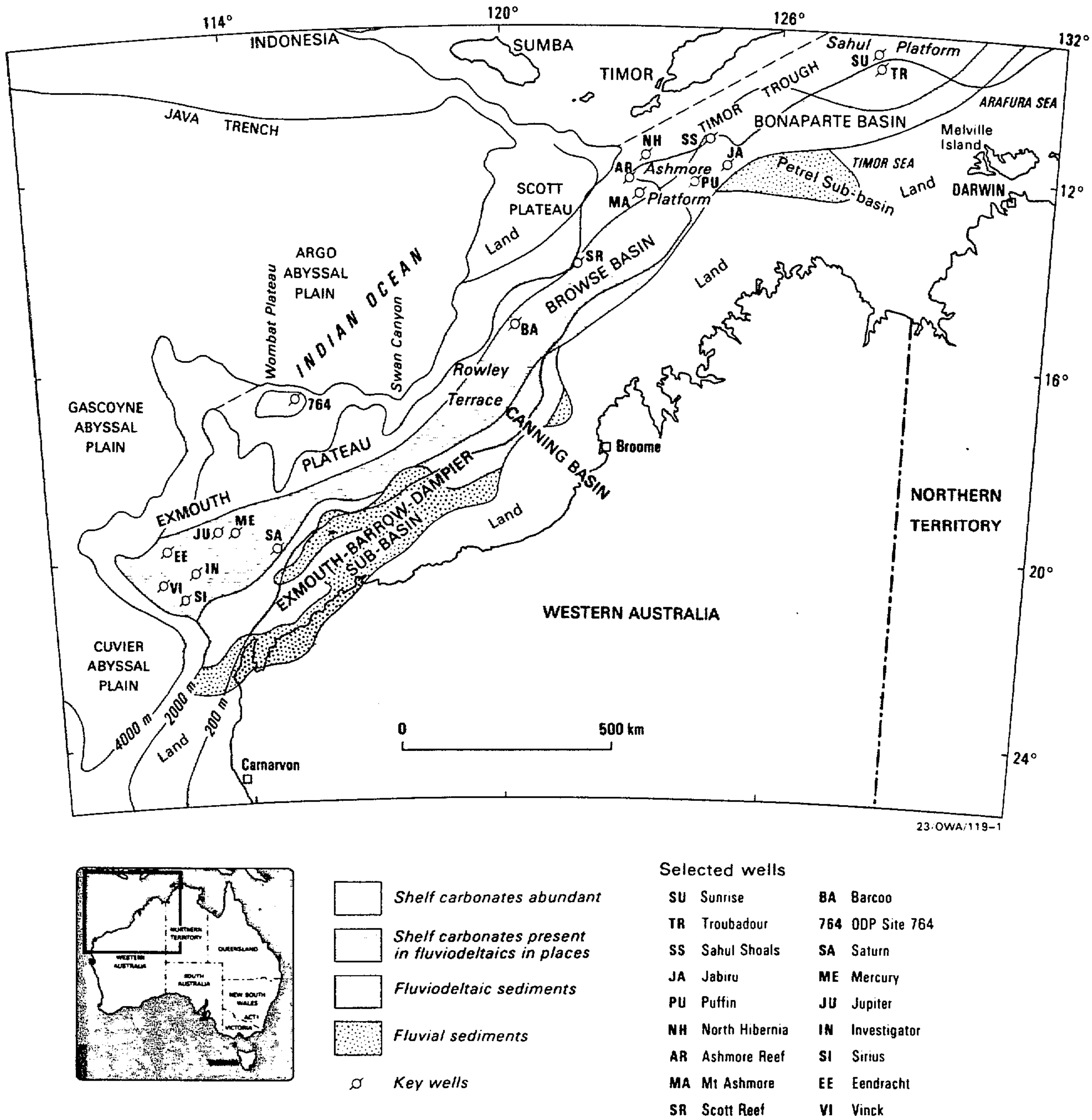


Figure 5. Late Triassic sedimentation on the North West Shelf, showing predicted zones of shelf carbonate development (after Williamson and others, 1989).

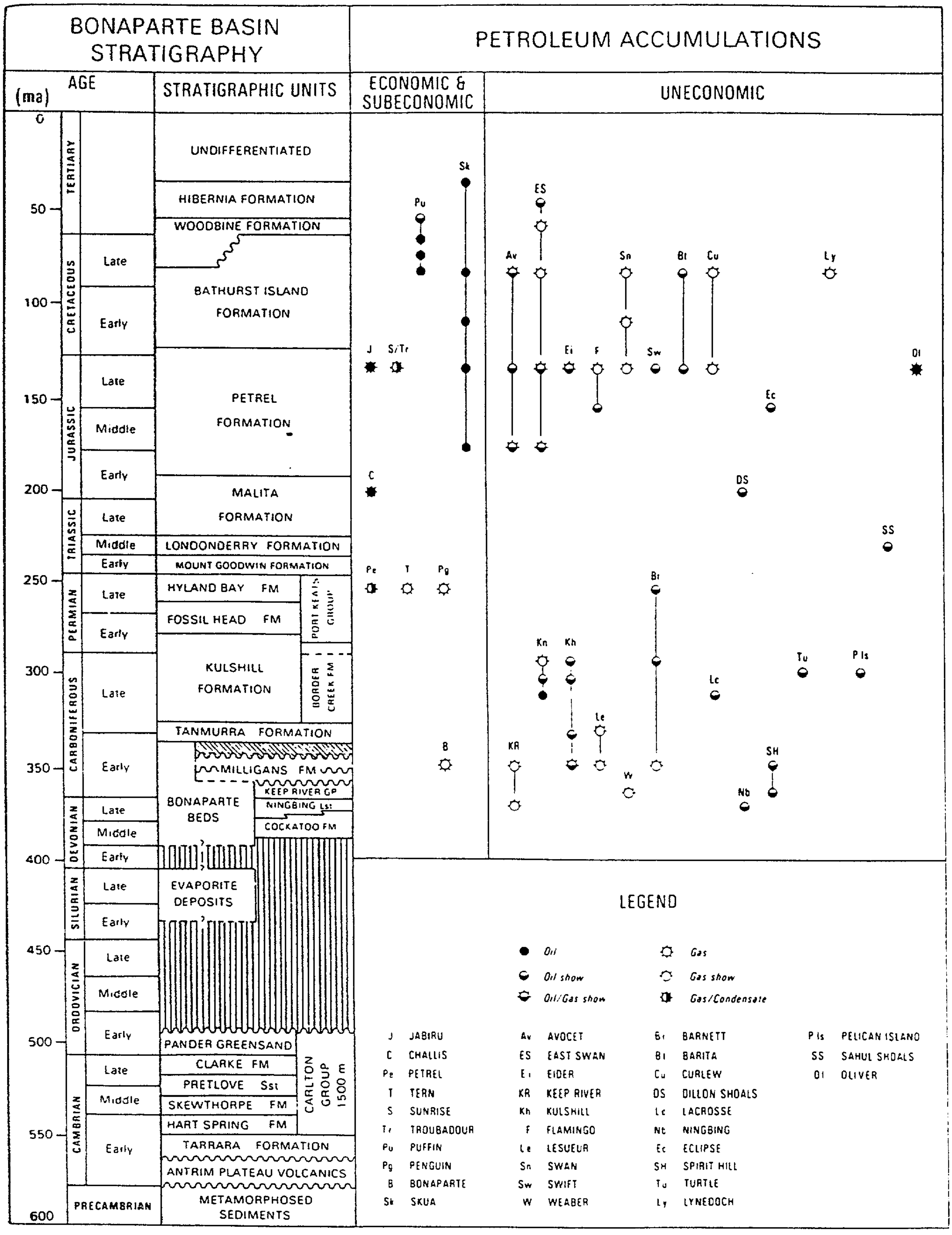


Figure 6. Stratigraphic setting of Bonaparte Basin petroleum accumulations.

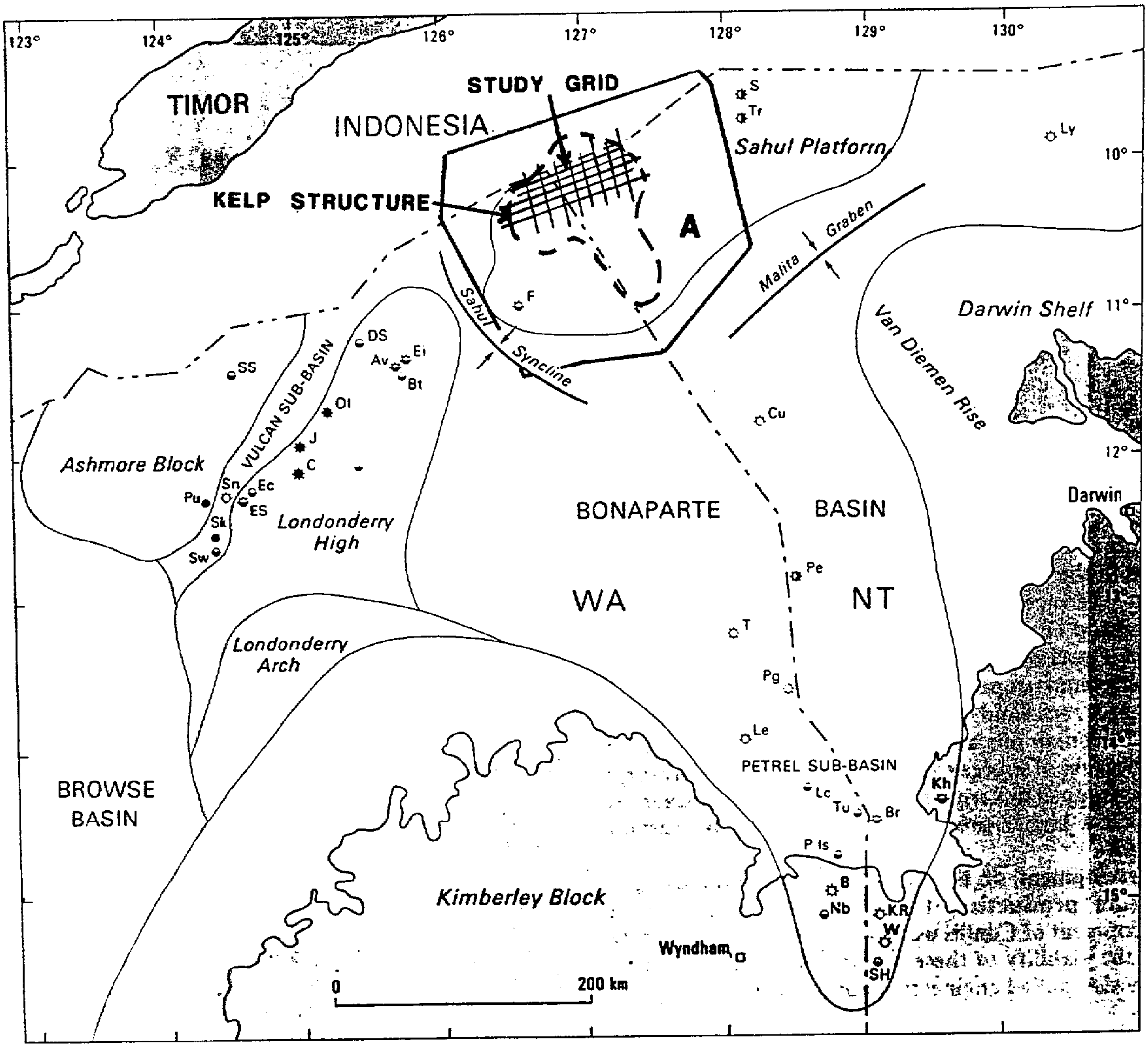


Figure 7. Location of study area in relation to Kelp structure.

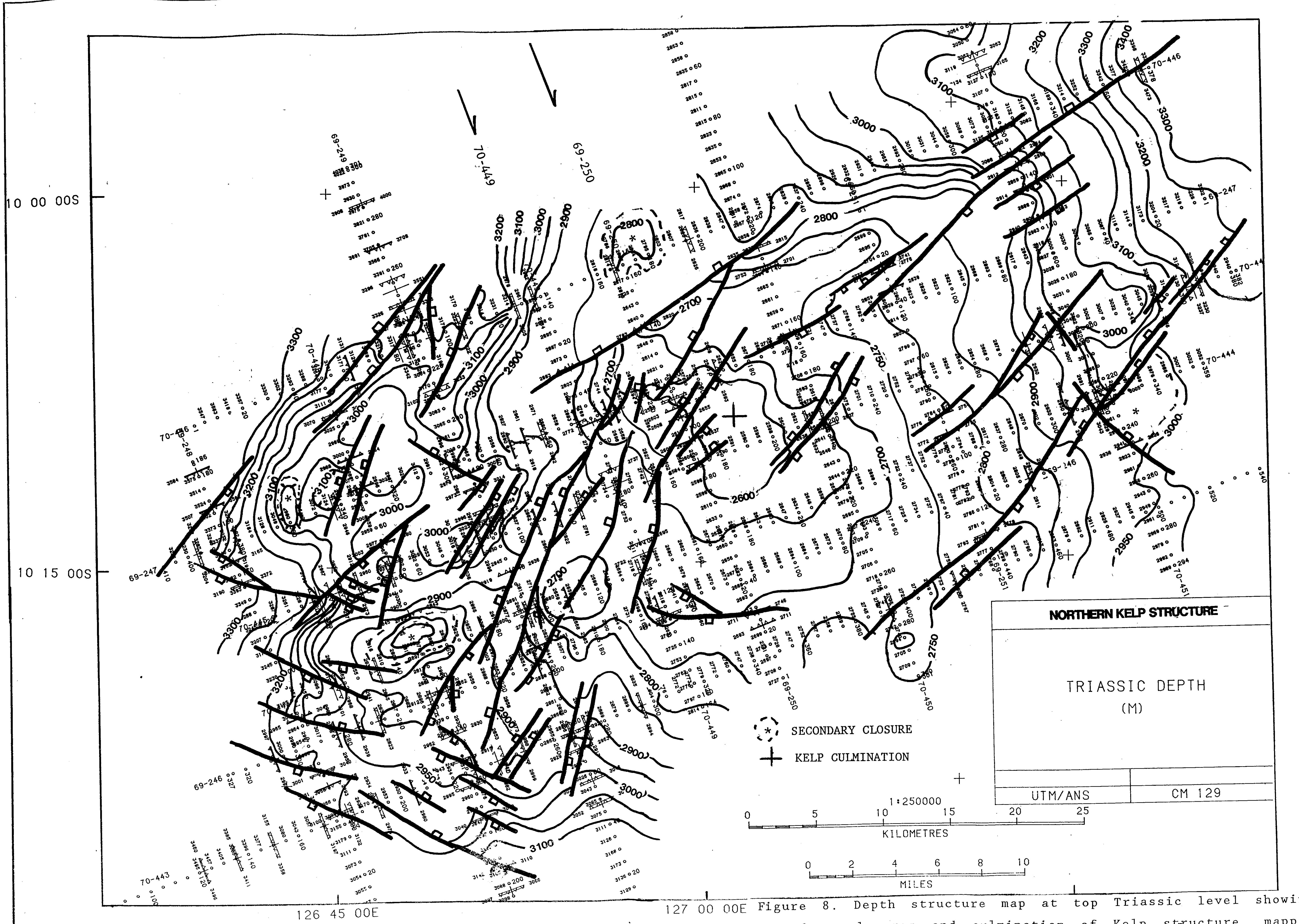


Figure 8. Depth structure map at top Triassic level showing secondary closures and culmination of Kelp structure, mapped using BOC seismic data collected in 1969 and 1979.

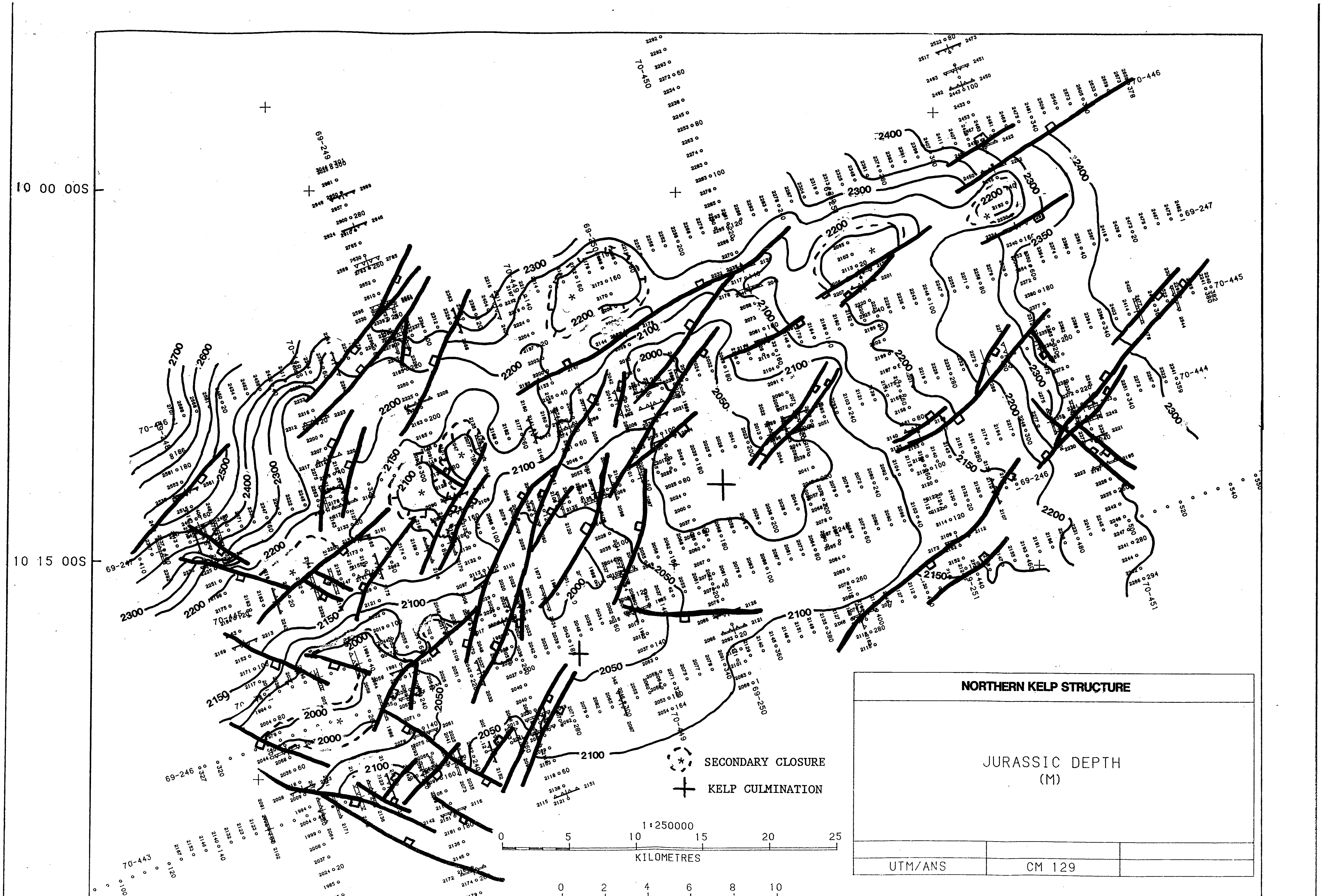


Figure 9. Depth structure map at top Jurassic level showing secondary closures and culminations of Kelp structure. Data used is given in Fig. 8.

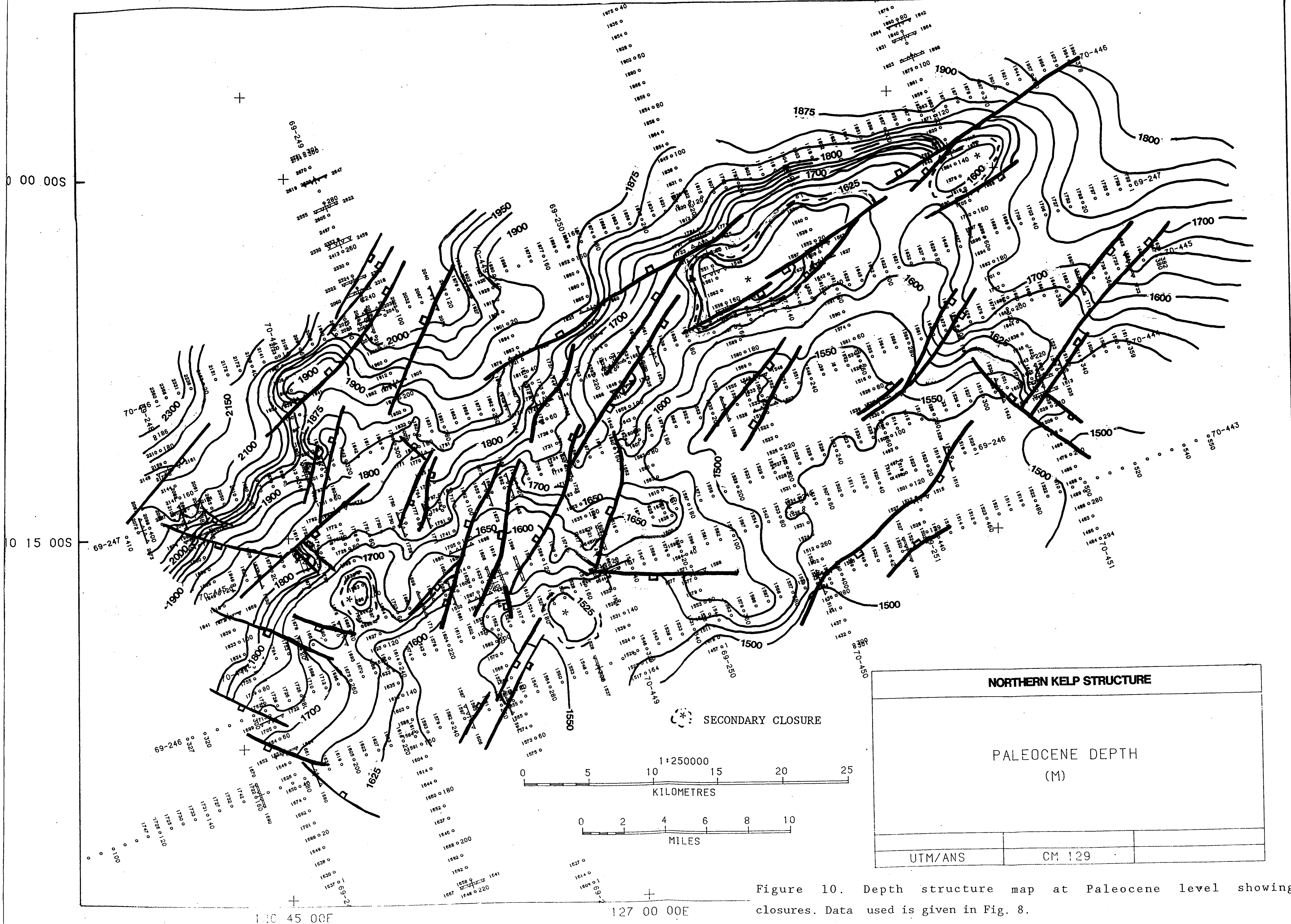


Figure 10. Depth structure map at Paleocene level showing closures. Data used is given in Fig. 8.

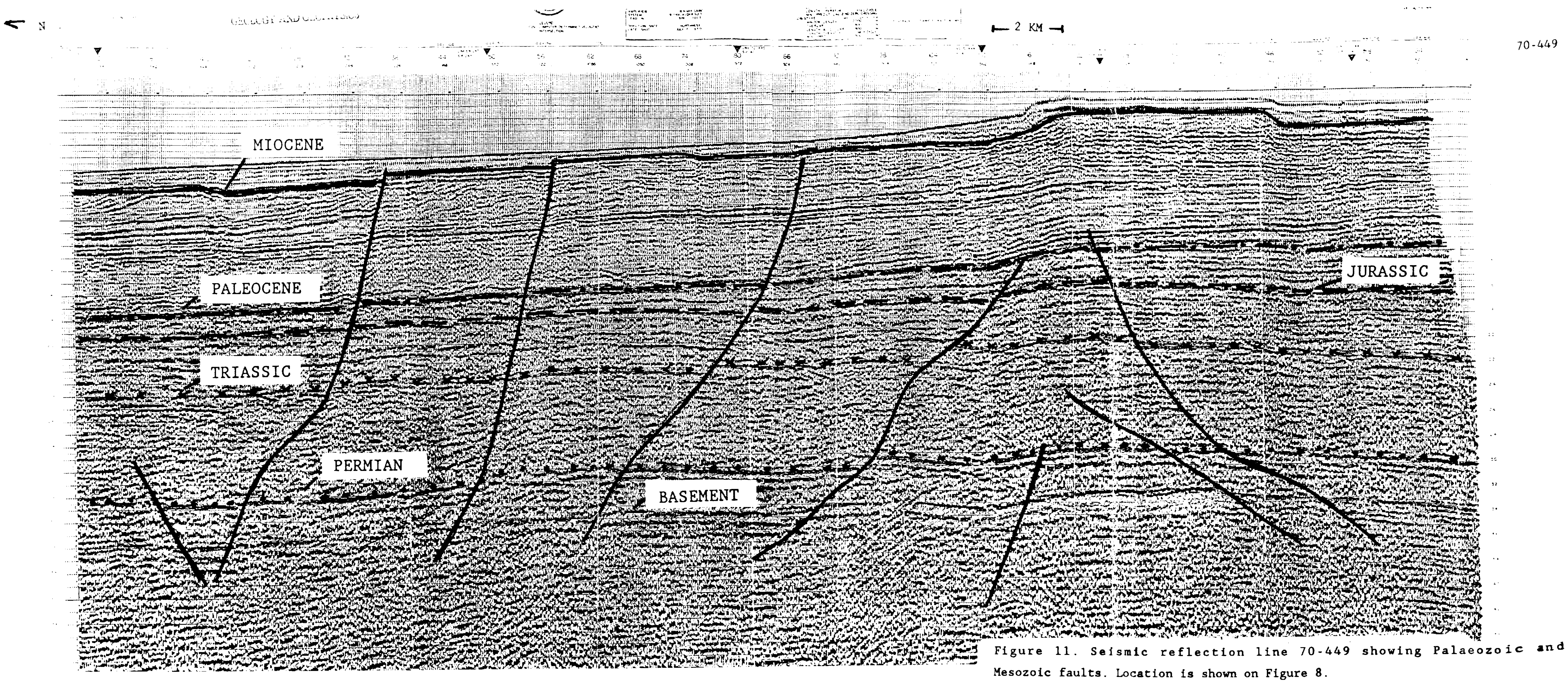


Figure 11. Seismic reflection line 70-449 showing Palaeozoic and Mesozoic faults. Location is shown on Figure 8.

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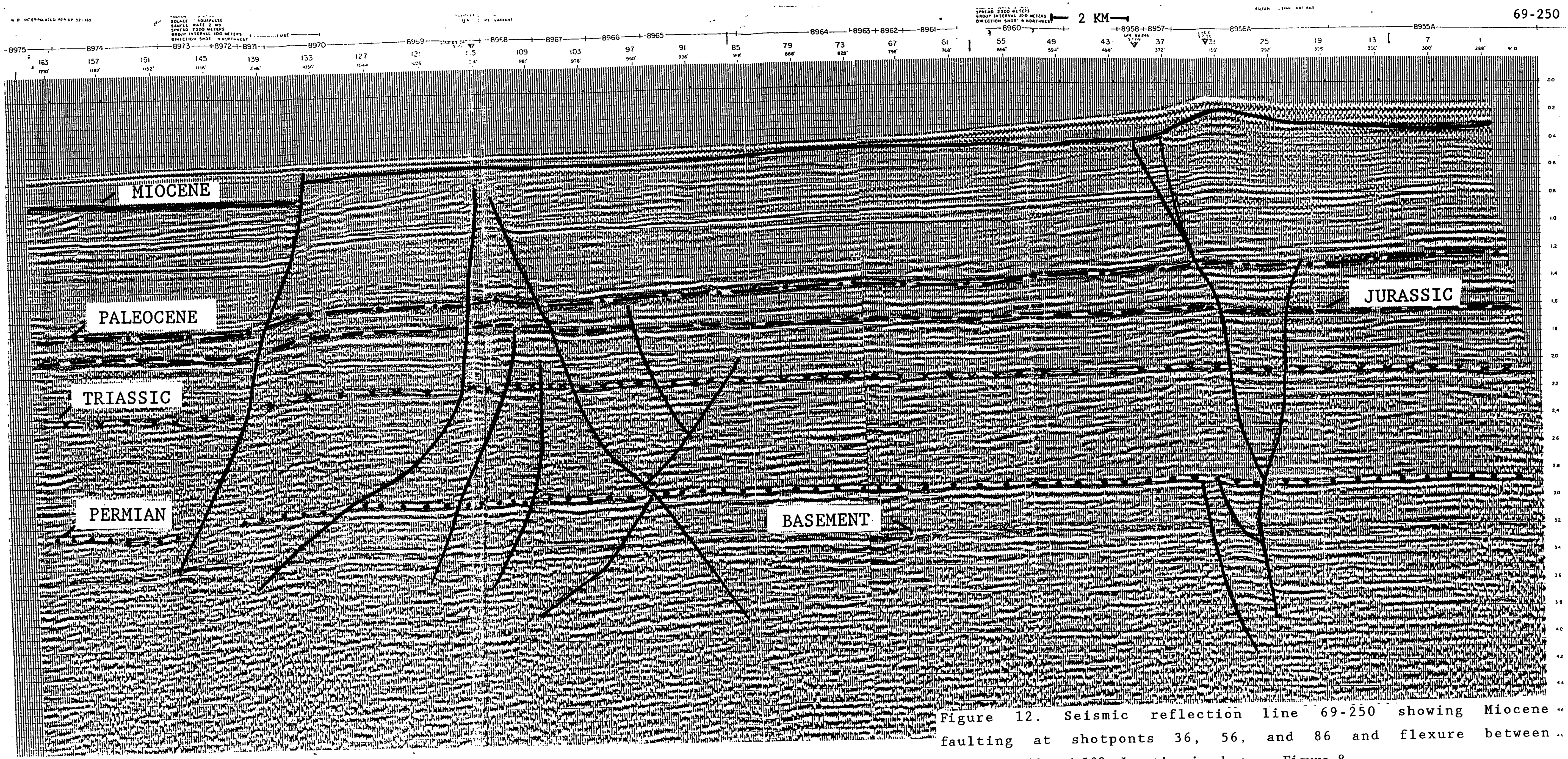


Figure 12. Seismic reflection line 69-250 showing Miocene faulting at shotponts 36, 56, and 86 and flexure between shotpoints 43 and 109. Location is shown on Figure 8.

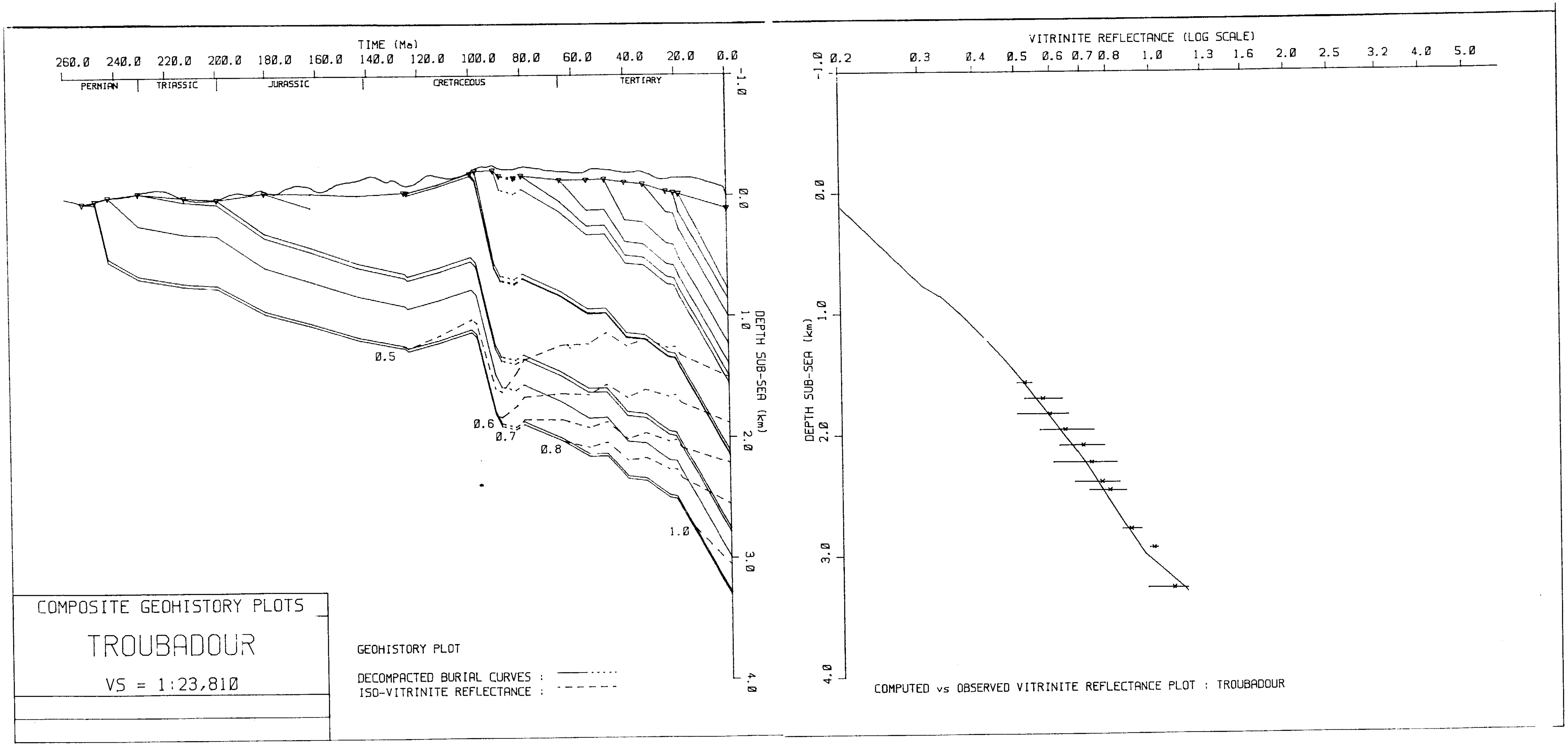


**Figure 13. Geohistory of Troubadour 1 well.**

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