SEISMIC STRATIGRAPHY OF THE GIANT FORESETS FORMATION, OFFSHORE NORTH TARANAKI–WESTERN PLATFORM

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Abstract

The Plio-Pleistocene Giant Foresets Formation has been investigated in the offshore North Taranaki region (longitudes 172°E-174°E and lattitudes 38°S-39°S), using seismic reflection profiles and exploration well data. The formation is divided into four seismic facies above a prominent seismic reflector dated as base Pliocene. The topset facies is characterized by subparallel continuous reflectors, the progradational foresets facies by subparallel continuous reflectors in a clinoform pattern, the degradational foresets facies by chaotic offlapping low-amplitude reflectors, and the bottomset facies by moderate-amplitude, subhorizontal reflectors of variable continuity.

Five continous reflectors have been mapped, three within the formation and two facies bounding it. The three internal reflectors terminate towards the upper boundary by toplap and erosional truncation, and the lower boundary (base Pliocene) by downlap. Termination of the three internal reflectors toward both upper and lower boundaries suggests that the latter are correlative unconformities bounding one depositional sequence. The mapping results of the prominent internal reflectors show that the foresets prograded from southeast to northwest as part of a large lobe. The geometry of the formation suggests it is a "high stand system tract", which developed during early Opoitian (5.0 Ma) to Mangapanian (2.6 Ma) time when the rate of the sediment supply was higher than the rate of basement subsidence.

Introduction

The name "Giant Foresets Formation" was first used by Shell BP Todd Oil Services Ltd (1977) to describe a formation consisting of mudstones, siltstones and sandstones deposited in about 5 million years during the Plio-Pleistocene. Interpretations of seismic data in the Western Platform and the western part of the North Taranaki Basin show that this formation is characterized by prograding clinoforms typified by foreset beds, with buried slope channels, dipping to the northwest (Thrasher, 1988). The total thickness is about 2.2 km, about half of the stratigraphic thickness in much of the Western Platform (Beggs, 1989). The Giant Foresets Formation is divided into four facies based on seismic character, namely: topset, progradational foreset, degradational foreset, and bottomset facies.

The study area is located in offshore Taranaki between coordinates 172°E- 174°E, 38°S- 39°S, and comprises an area of about 17000 km² (Figure 1). New Plymouth is the nearest city, about 175 km to the southeast. This area was actively explored by oil companies from 1968 to 1984, including the acquisition and processing of marine seismic reflection data and the drilling of six exploration wells (Figure 2).

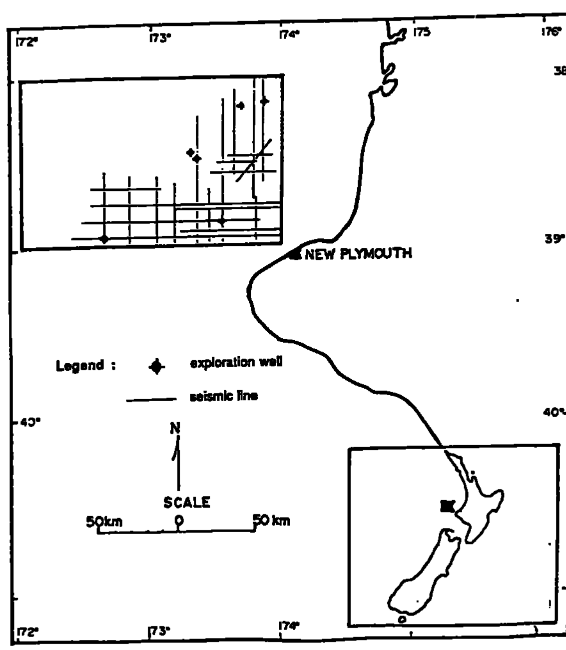


Figure 1: Location map.

The aims of this study are the folowing:
(i) to produce, in detail, isopach maps of the Giant Foresets Formation from available seismic reflection profiles;
(ii) to interpret the maps and profiles using seismic stratigraphic concepts to determine in detail the direction of progradation of the formation;
(iii) to reconstruct a chronostratigraphic chart which shows how the formation evolved by using biostratigraphic data from a well (Taimana-1); and
(iv) to discuss the factors which influenced its evolution.

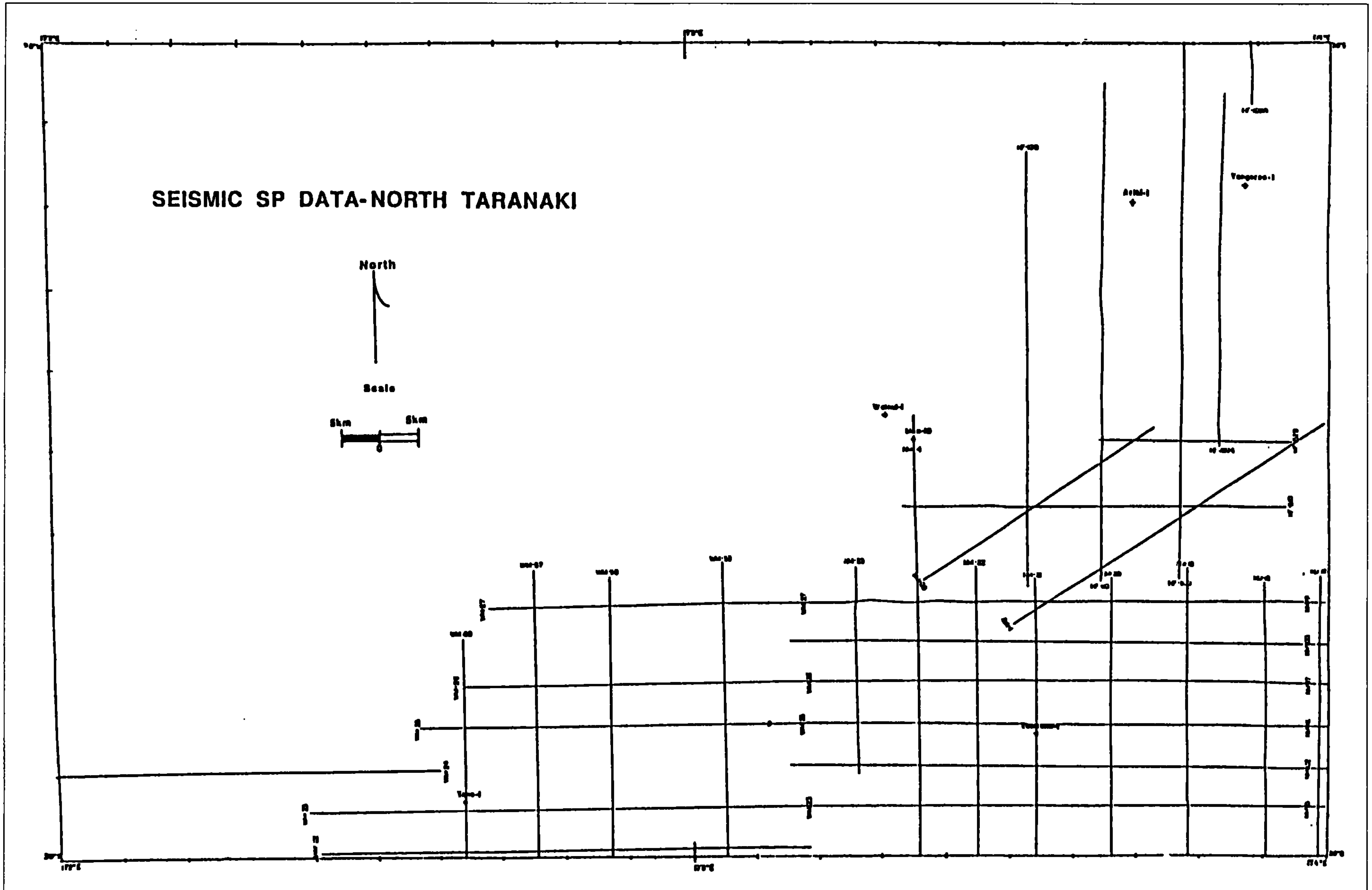


Figure 2: Shot point position map of the North Taranaki Basin.

Regional Setting and Stratigraphy

The Giant Foresets Formation was produced by the northward progradation of sediment eroded during reverse faulting and structural inversion of the southern Taranaki Basin and the northwestern part of the South Island. This deformation began in in the Miocene and was renewed in Plio-Pleistocene time (Knox, 1982). Tilting of older sediments in the southern Taranaki Basin and erosion of the uplifted strata produced a vast amount of sediment that rapidly prograded across the Western Platform and the western part of the North Taranaki Graben (Kamp, 1986). The paleogeography during the deposition of these sediments in the Lower Pliocene and their position in the stratigraphic column of the Western Platform and North Taranaki Graben are shown in Figure 3 (King and Robinson, 1988).

Interpretation Procedure and Results

The general feature of the Giant Foresets Formation can be seen in both N-S and E-W seismic reflection profiles. The formation appears as a prograding series of clinoforms that dips toward the north and west. These clinoforms consist of high to medium amplitude reflectors which form a sigmoidal pattern. At the top and bottom, the clinoforms are bounded by subparallel reflectors with high to medium amplitudes (Figures 4A, 4C, 5A, 5C). In the east of the study area these seismic patterns are interrupted by discontinuities in the reflectors which are interpreted as normal faults associated with an Upper Miocene volcano (G. Thrasher, pers. comm. 1991). However, to the west and north, the prograding clinoforms change from a smooth to a contorted and hummocky reflection configuration which probably indicates the end of the development of these clinoforms.

The parallel to subparallel reflections that confine the prograding clinoform patterns are interpreted as topset facies and bottomset facies; the clinoforms are interpreted as the prograding foresets facies (Beggs, 1989). Topset, progradational/degradational and bottomset facies as they occur in this study area are shown in Figure 6. The topset facies is marked by subparallel continuous reflectors; the progradational foresets by coherent offlapping moderate-amplitude reflectors; the degradational foreset facies by chaotic offlapping low-amplitude reflectors; and the bottomset facies by moderate-amplitude subhorizontal reflectors of variable continuity.

The progradational foreset facies downlaps onto the strong continuous reflector (yellow horizon), mapped by Thrasher and Cahill (1990) and dated as base Pliocene, and terminates beneath the topset facies by toplap. In order to study the attitude of these clinoforms (the progradational foresets facies) and their relationship to the top and bottomset facies, this study maps four prominent internal reflectors that can be traced throughout the study area. These reflectors are labelled (from top to bottom) red, pink, green, and blue.

The red reflector is characterized by high to medium amplitude in the south and east, but it changes to medium to

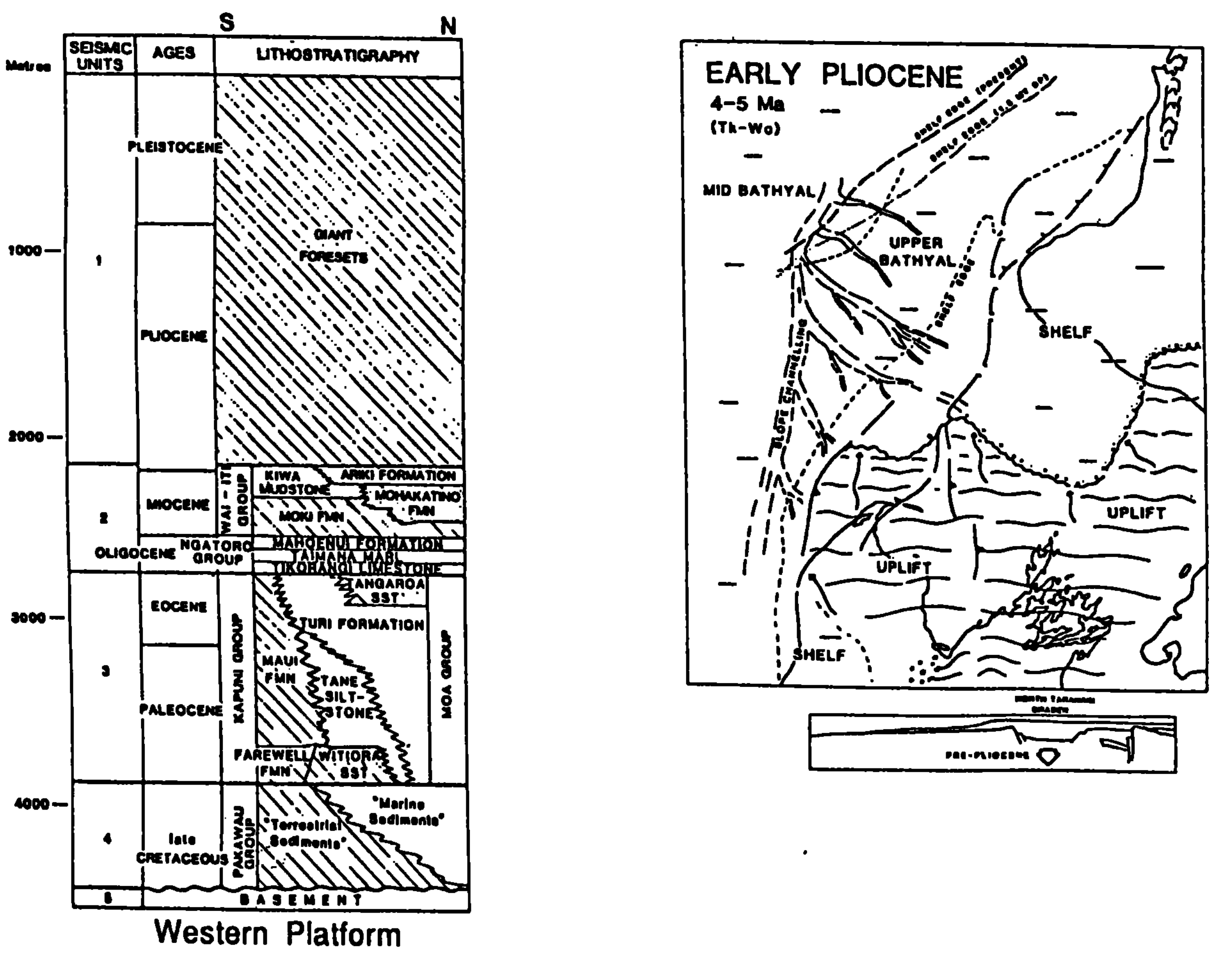
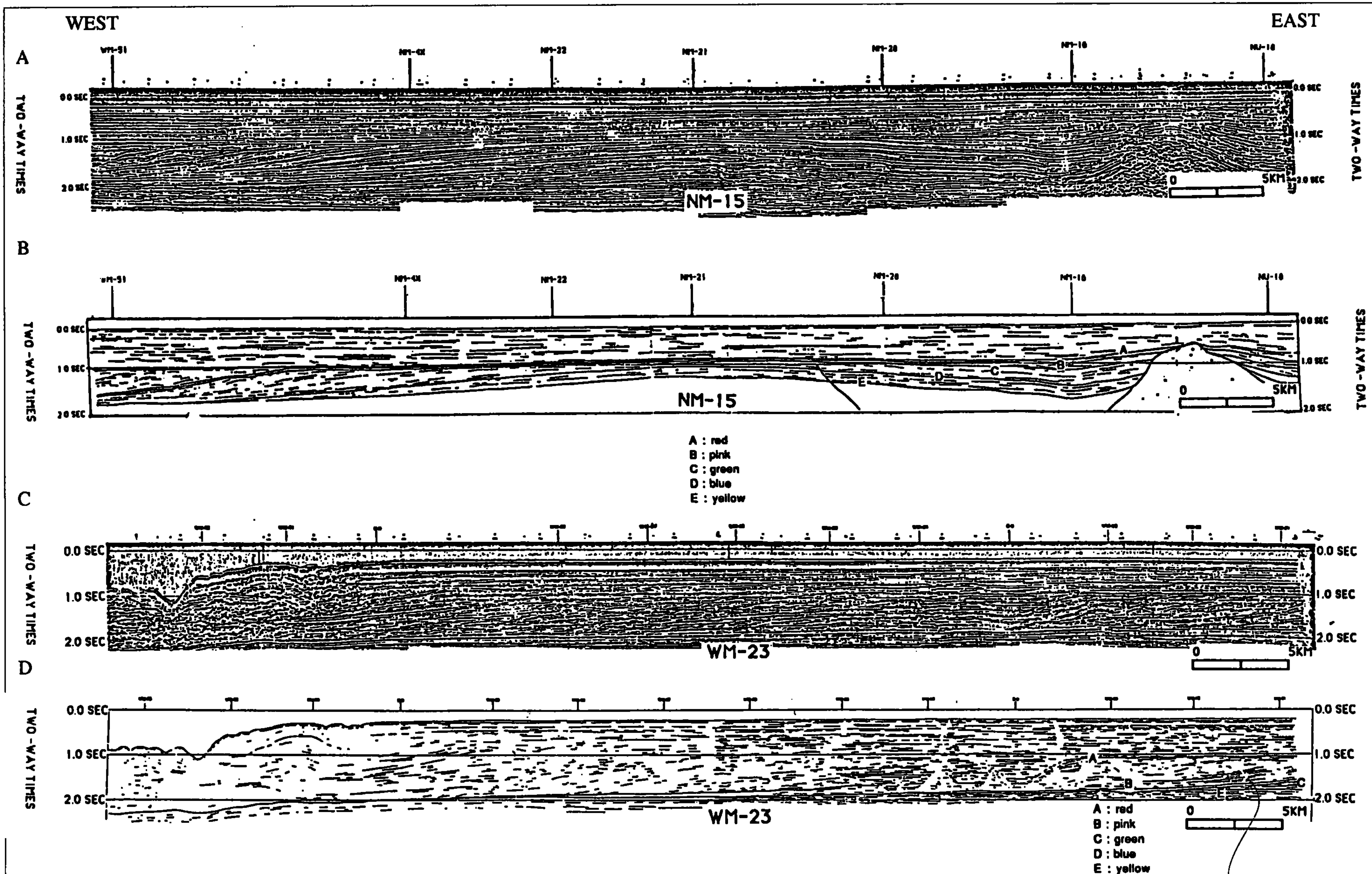


Figure 3: The stratigraphic column and the Early Pliocene paleogeography map of the Western Platform – North Taranaki Graben (from King and Robinson, 1988).



Figures 4A: Uninterpreted seismic reflection profile of NM-15; 4B: Interpreted seismic reflection profile of NM-15; 4C: Uninterpreted seismic reflection profile of WM-23; 4D: Interpreted seismic reflection profile of WM-23.

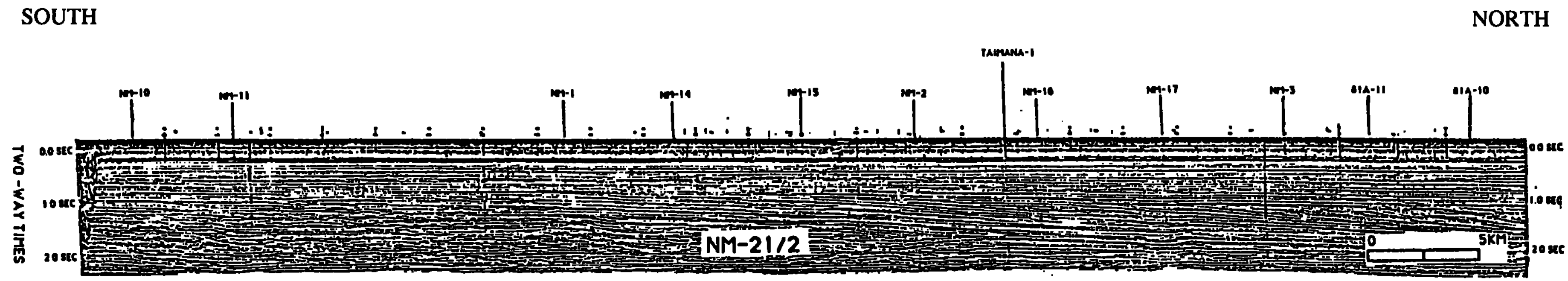


Figure 5A: Uninterpreted seismic reflection profile of NM-21.

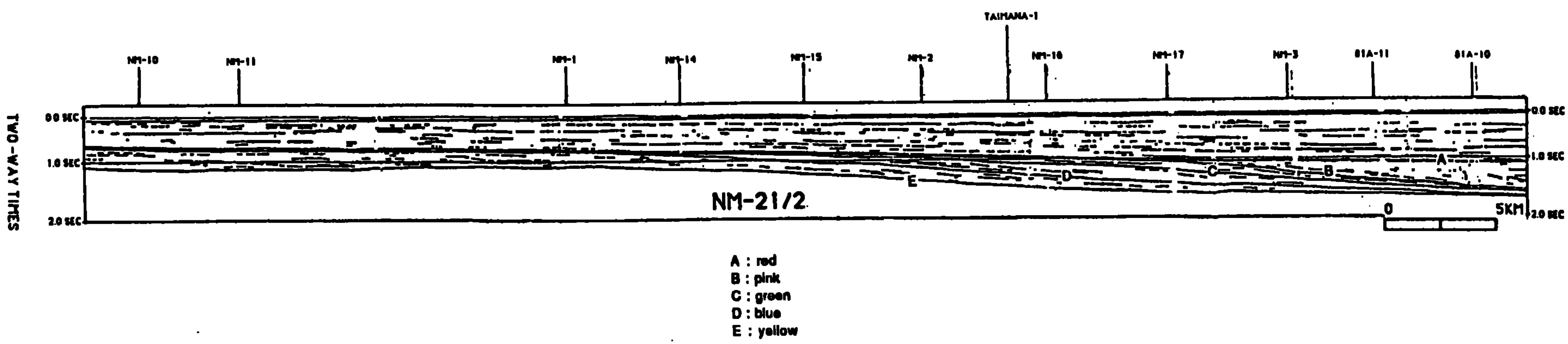


Figure 5B: Interpreted seismic reflection profile of NM-21.

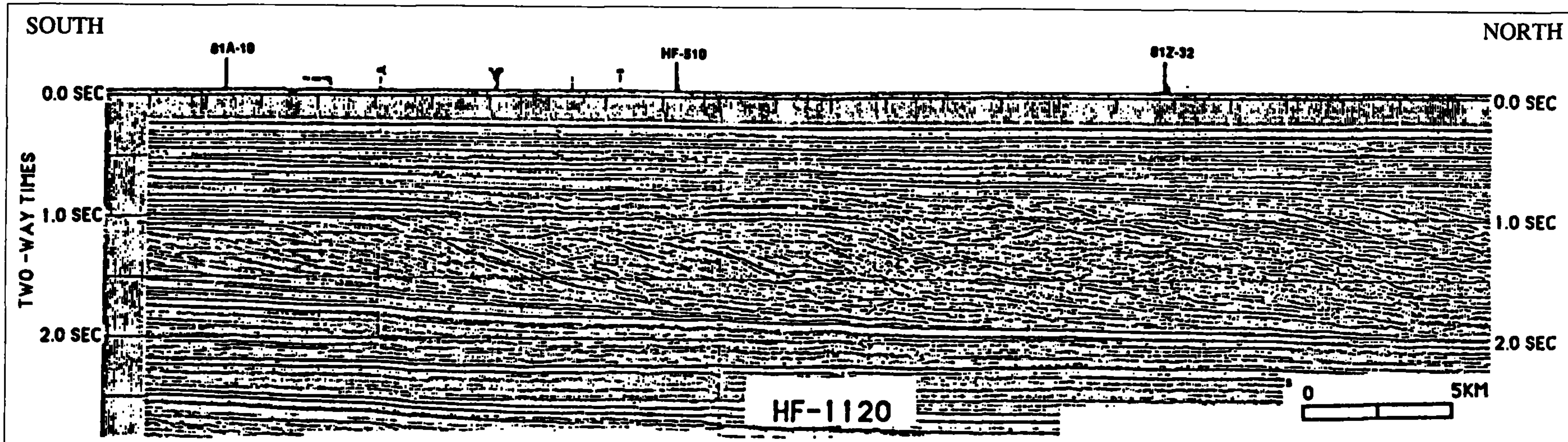


Figure 5C: Uninterpreted seismic reflection profile of HF-1120.

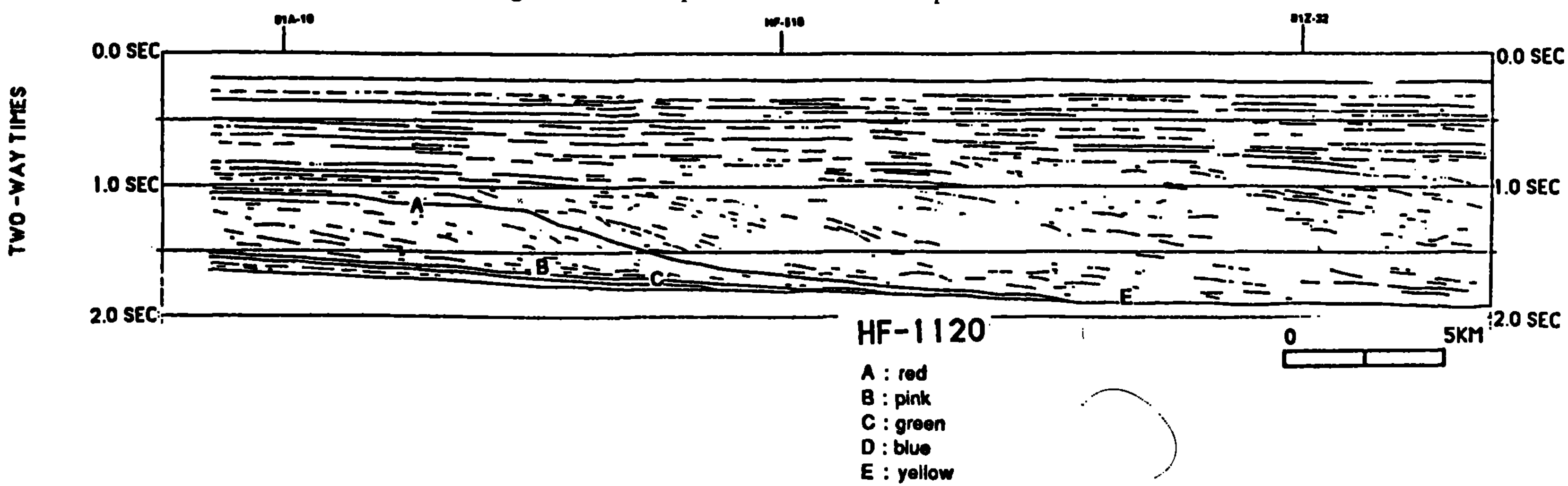


Figure 5D: Interpreted seismic reflection profile of HF-1120.

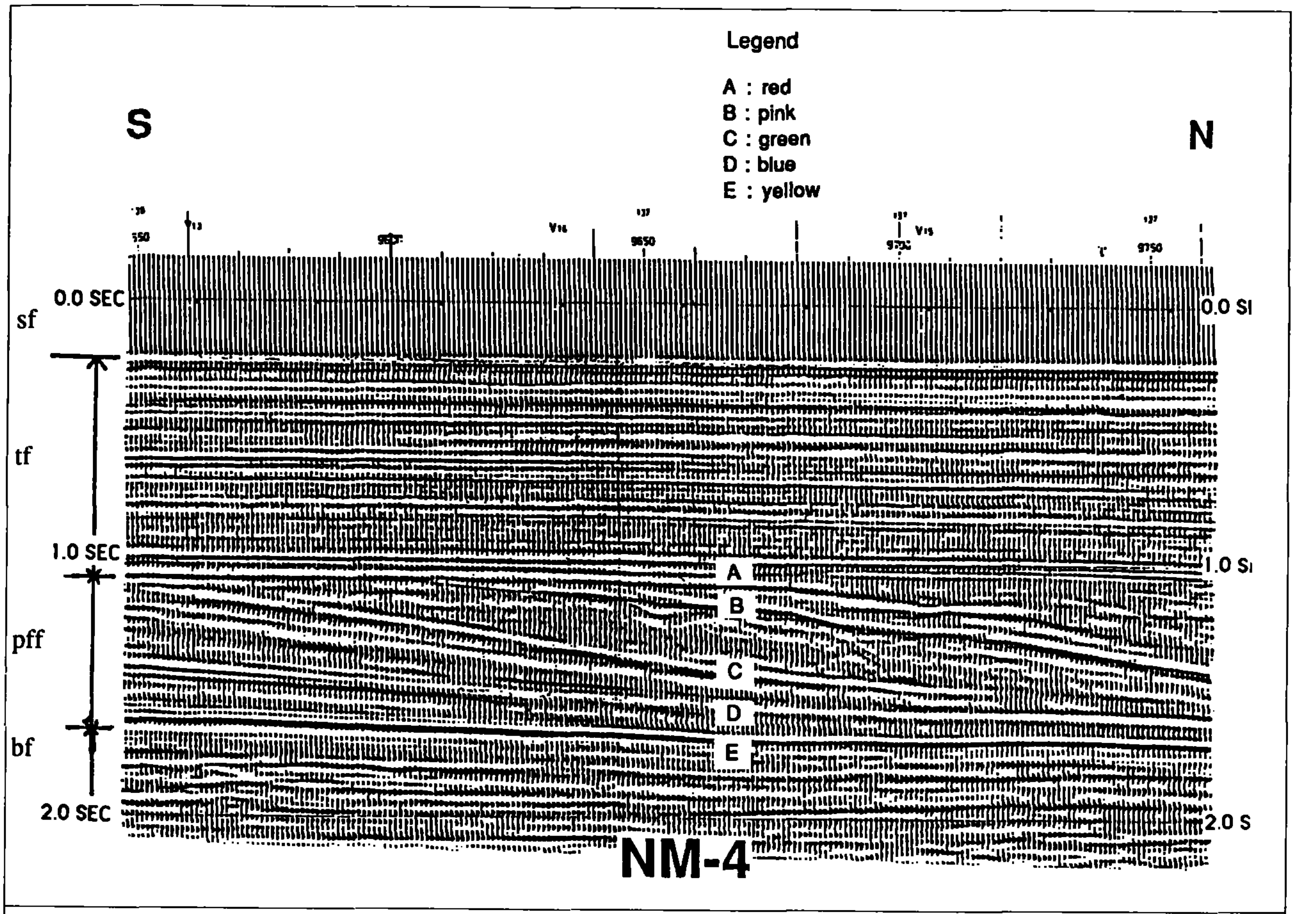


Figure 6: Topset, progradational/degradational and bottomset facies (sf: sea-floor, tf: topset facies, pff: progradational foreset facies, bf: bottomset facies).

low amplitudes in the north and west. The pink reflector is toplapped by the red reflector as shown on line NM-16 at SP 920-1050 (Figure 7). The distance between the red reflector and the lower reflectors narrows towards the south, as shown on line NM-21 (see Figure 5B). To the south beyond the study area, these reflectors probably terminate against the red reflector. These terminations suggest that the red reflector is a correlative seismic unconformity. Also, because the position of this reflector is at the top of the progradational foresets facies and all the reflectors above it are parallel to it, the red reflector is therefore a boundary between this facies and the topset facies. To the north and west, however, the red reflector decreases in reflectivity, is surrounded by chaotic to hummocky patterns, and downlaps onto the yellow reflector (Figures 4B, 4D, 5B and 5D).

The pink reflector is characterized by high to medium amplitudes and is well-developed in the study area except on line NM-16 from SP 920-1050 (see Figure 7) where it is toplapped by the red unconformity, suggesting erosional truncation. To the north and west, the pink reflector downlaps onto the yellow reflector, but to the south the pink reflector onlaps the green reflector as shown on NM-21 at SP 6720 (Figure 5B).

The next-oldest reflector is the green reflector, which is marked by high to medium amplitudes. To the north and west, this reflector also downlaps onto the yellow reflector. To the south and east outside the study area however, the green reflector probably toplaps against the red reflector.

The blue reflector is the lowest of the clinoform package. It is characterized by medium amplitudes and downlaps onto the yellow reflector in the north and west of the study area.

The evolution of the clinoforms can be appreciated from a map showing the downlap position of each reflector (Figure 8). This map shows the prograding clinoforms to be part of a large fan lobe which prograded from the southeast to the northwest. This end of the clinoforms is also characterized by an onlap fill seismic facies unit which can be interpreted as a channel. The eastern part of this lobe has been affected by two normal faults and an igneous body. The faults are part of the Cape Egmont Fault Zone, the igneous body is an Upper Miocene volcano (G.P. Thrasher, pers. comm., 1991) which is related to the Cook-Turi Lineament (Knox, 1982).

The results of the mapping of these prominent reflectors are described using two-way travel time (TWT maps). These maps show that depositional dips on all of these reflectors in this study, except the yellow, are developed around Taimana-1. Based on this observation, the conversion from TWT to depth has been done by using the "time-depth curve" (TDC) derived from the checkshot data in this well (Figure 9). The results of this conversion are shown as structure contour maps for all the prominent reflectors (Figures 10, 11, 12, 13 and 14). The general direction of progradation of the Giant Foresets Formation is to the northwest as shown by Thrasher (1988). This direction of progradation can also be shown by reconstructing isopach maps between each pair of the yellow, blue, green, pink and red reflectors. These isopach maps are shown in Figures 15, 16, 17 and 18. The maximum total thickness west of the fault zone of the clinoform or the progradational foresets facies is 900 m (Figure 19). A map of the thickest part of each interval (Figure 20) shows that younger intervals reach their maximum thicknesses northwest

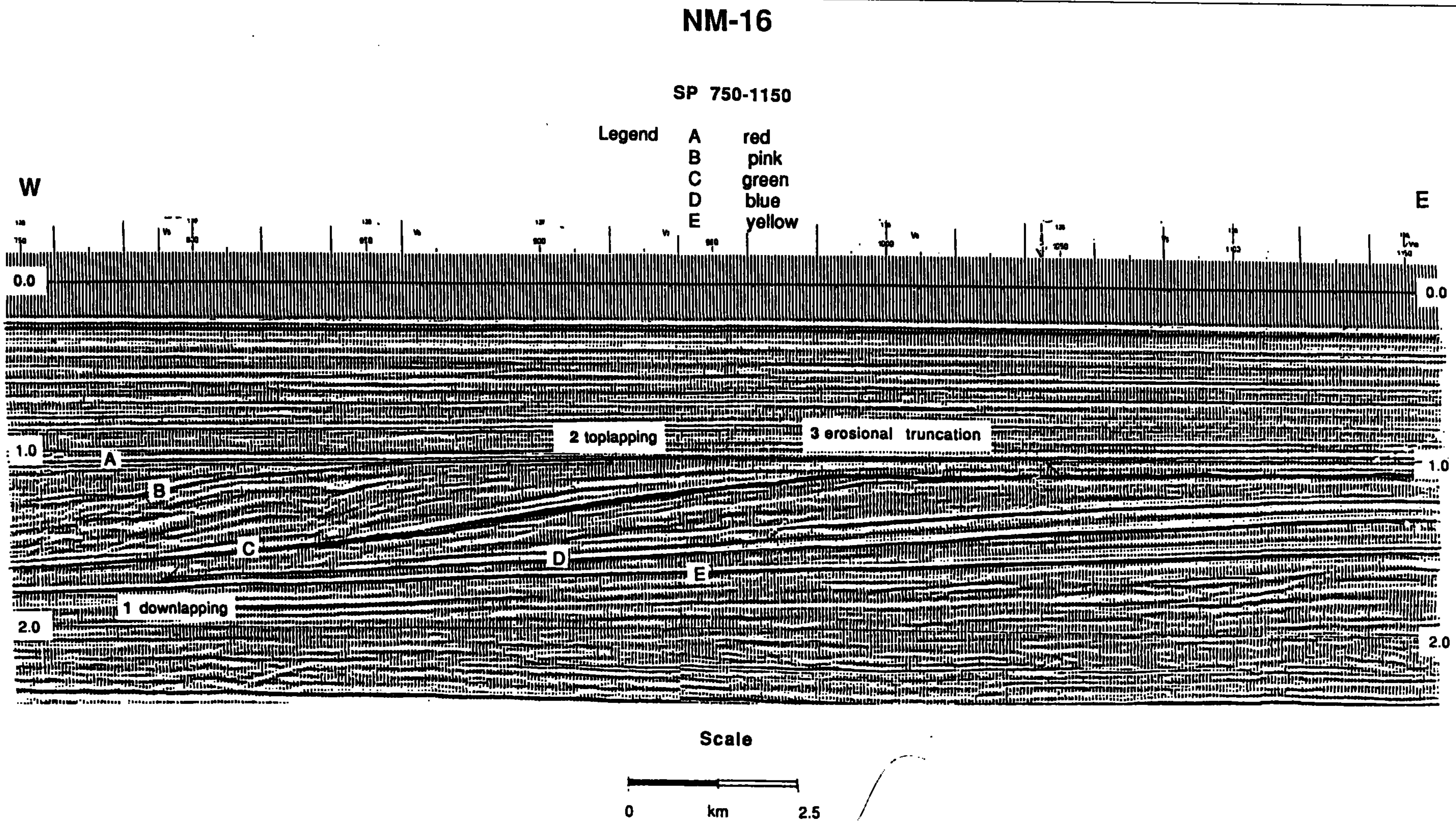


Figure 7: Interpreted profile of NM-16 shows the pink is toplapped by the red at sp 920-1050.

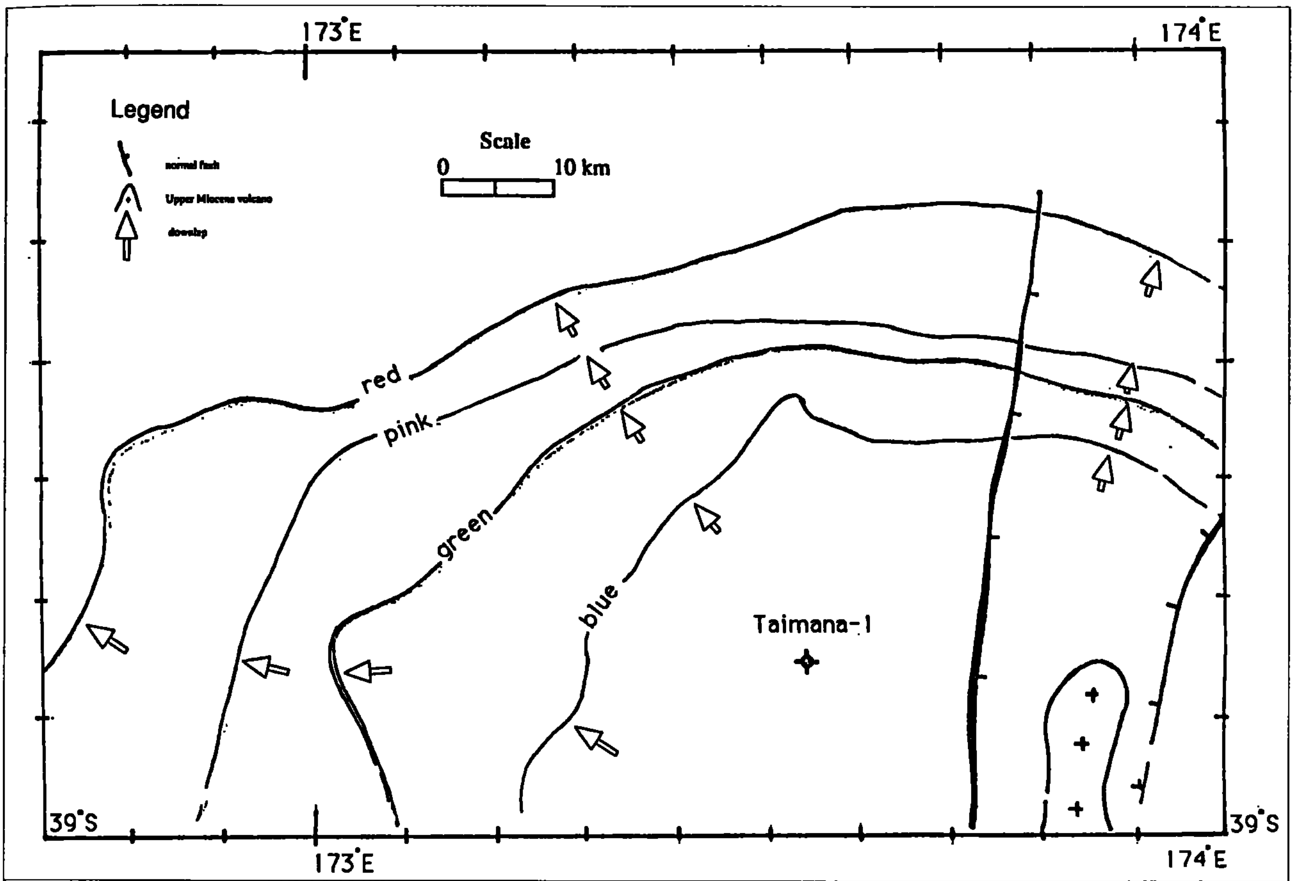


Figure 8: Downlap map.

of older ones. Thickness and progradation patterns in the graben area, however, are irregular and difficult to determine due to deformation.

Discussion

In order to understand the development of the Giant Foresets Formation (represented by the red, pink, green, blue and yellow reflectors) through time this study uses the sequence stratigraphic interpretation method (Vail *et al.*, 1977, 1988). A chronostratigraphic chart was constructed from two profiles in the east-west and north-south directions across the exploration well, where dating is available from the biostratigraphy. These two profiles (Figures 21 and 22) were drawn from the structure contour maps of all reflectors, based on lines NM-16 and WM-25 (east-west) and lines NM-21 and HF-1120 (south-north). The termination of all reflectors by downlap onto the yellow reflector at the base and by toplap against the red reflector suggest that the red and yellow reflectors are correlative seismic unconformities. The pink, green and blue reflections are between the two major unconformities, and are by definition (Mitchum *et al.*, 1977) grouped in one depositional sequence. The position of each reflector on the well log of Taimana-1 is shown in Figure 23 and the sedimentation curve based on the recently revised biostratigraphy of Taimana-1 is shown in Figure 24 (G.H. Scott and J.M. Beggs, pers. comm., 1991). The best fit is shown by three points (A, B and C) using assumptions of condensed early Opoitian (eWo) and Mangapanian (Wm) sediments. By combining information in Figures 23 and 24, the age of each prominent reflector can be estimated. The ages are shown plotted on the two profiles in Figures 25 and 26. From these profiles, the chronostratigraphic chart shown in Figures 27 and 28 can be constructed.

The chronostratigraphic chart shows the position of the base Pliocene which is represented by the prominent yellow reflector (E) as a continous line. This continuity indicates that this reflector was well-developed in this profile during that time. It was followed by the deposition of the blue (D), green (C), pink (B) and red (A) reflectors. The downlap indicates the limit of the development of each prominent reflector, i.e. the development of the blue reflector ceased at 3.6 Ma (late Opoitian-Waipipian), the green reflector in 2.8 Ma (Mangapanian), pink at 2.65 Ma and the red reflector at 2.6 Ma. The truncation of the pink reflector suggests that this reflector in one part of this profile was eroded by the red reflector. This chart also shows that the faults in the eastern part of the profile moved after the deposition of this sequence finished.

The subparallel reflectors above the red reflector (topset facies) and below the yellow reflector (bottomset facies) indicate low energy deposition. However, the clinoform patterns of the progradational foresets facies (represented by the pink, green and blue reflectors) suggest that this facies was deposited in a high energy environment.

Revision of the biostratigraphy data in Taimana-1 (G.H. Scott, pers. comm., 1991) shows that from Opoitian to Nukumaruan the water depth was gradually shallowing from middle/upper bathyal (in Opoitian) to middle shelf (Nukumaruan). Above the Nukumaruan, the water depth deepened again to outer shelf. Sea level thus oscillated during that period.

Biostratigraphic and seismic stratigraphic analyses gave evidence that the progradational foresets facies was developed

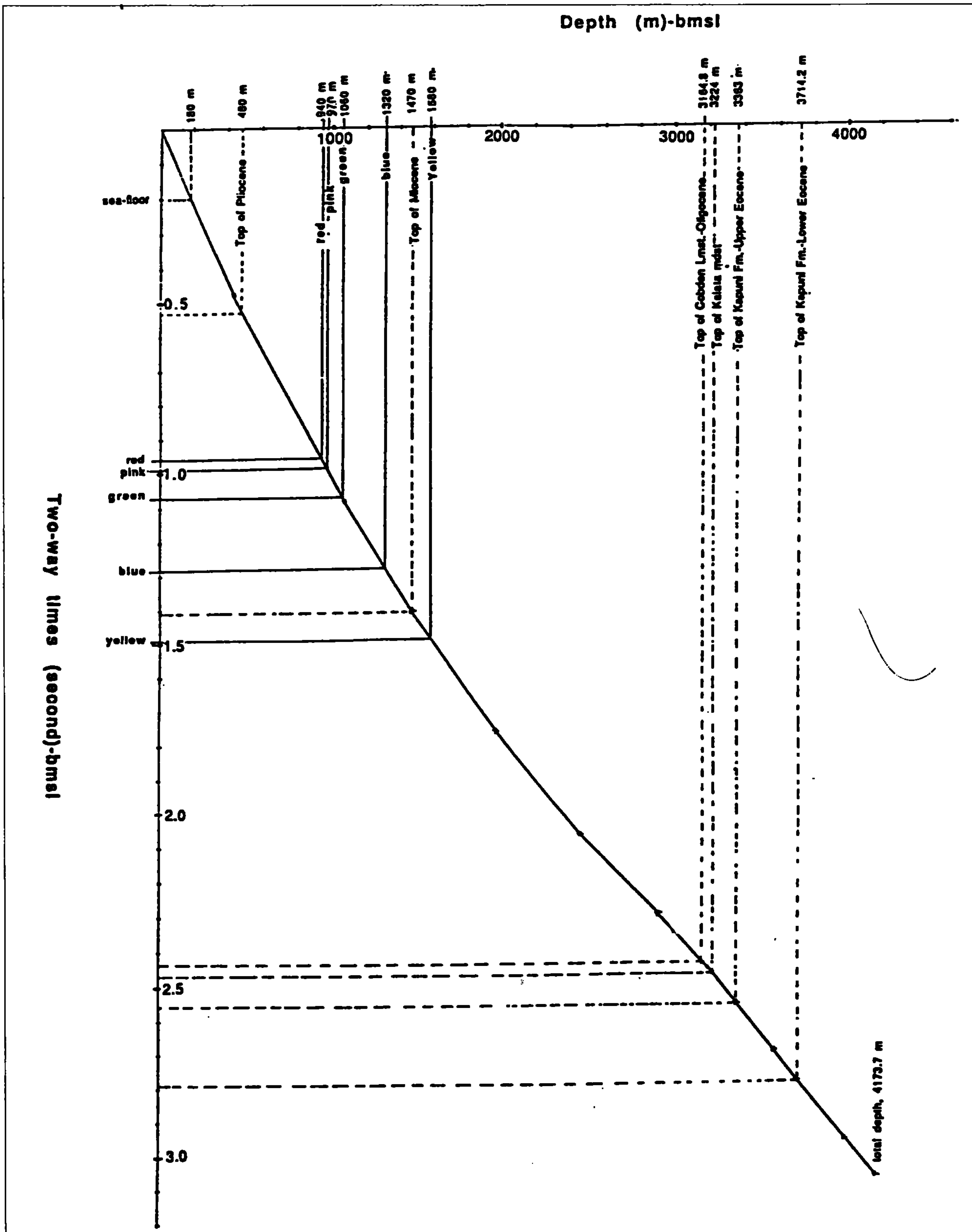


Figure 9: TDC of Taimana-1.

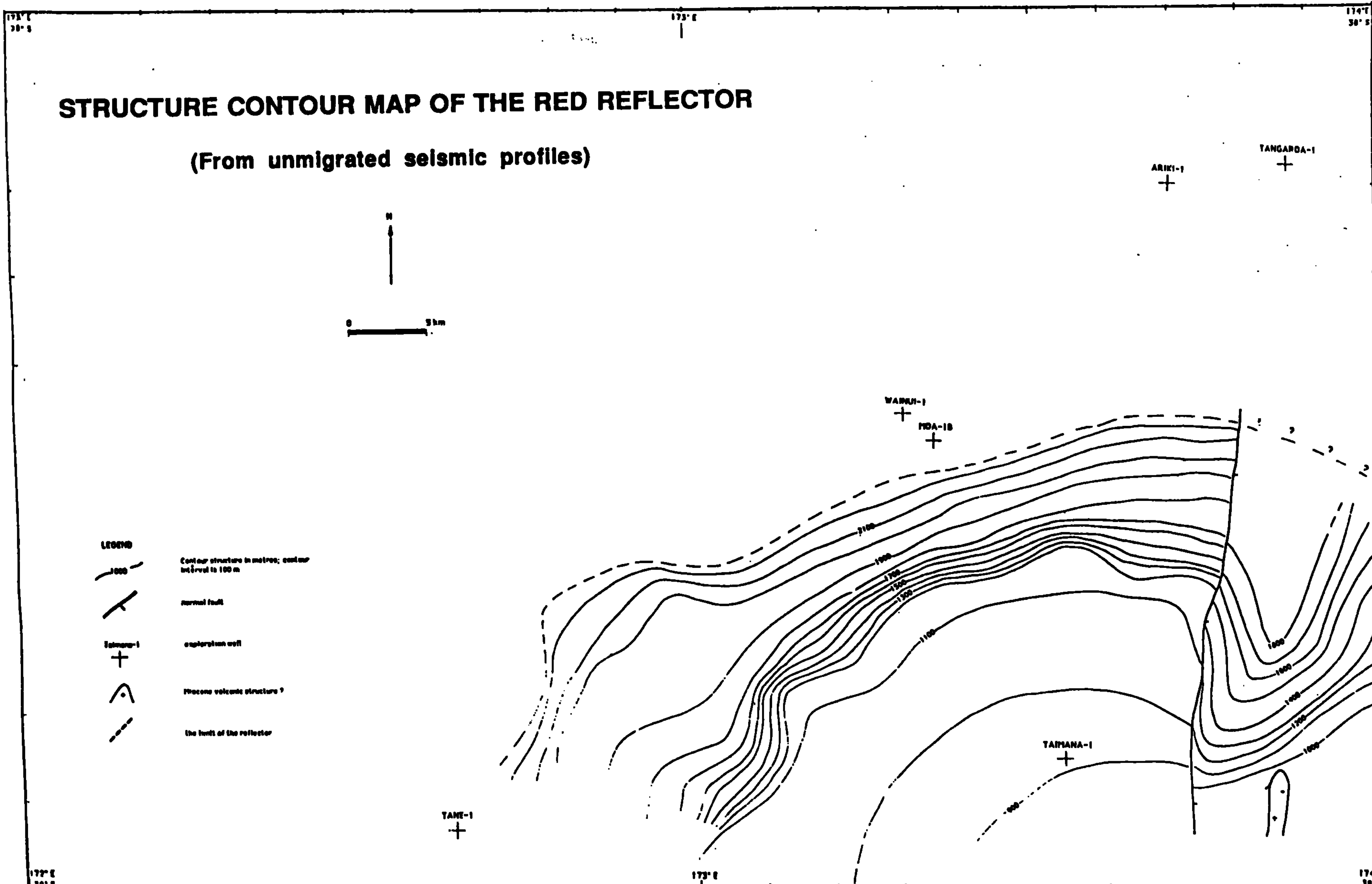


Figure 10: Structure contour map of the red reflector.

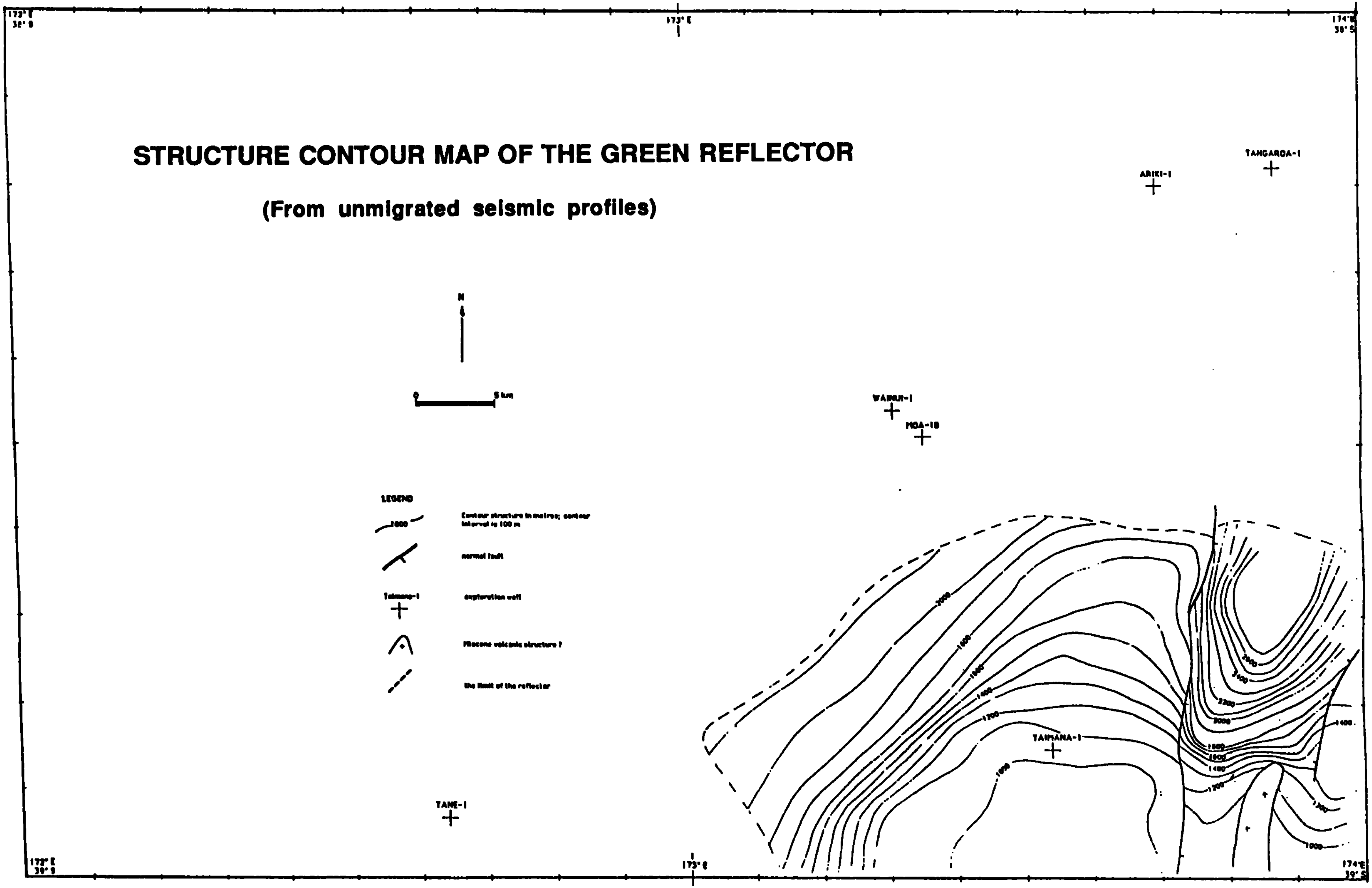


Figure 12: Structure contour map of the green reflector.

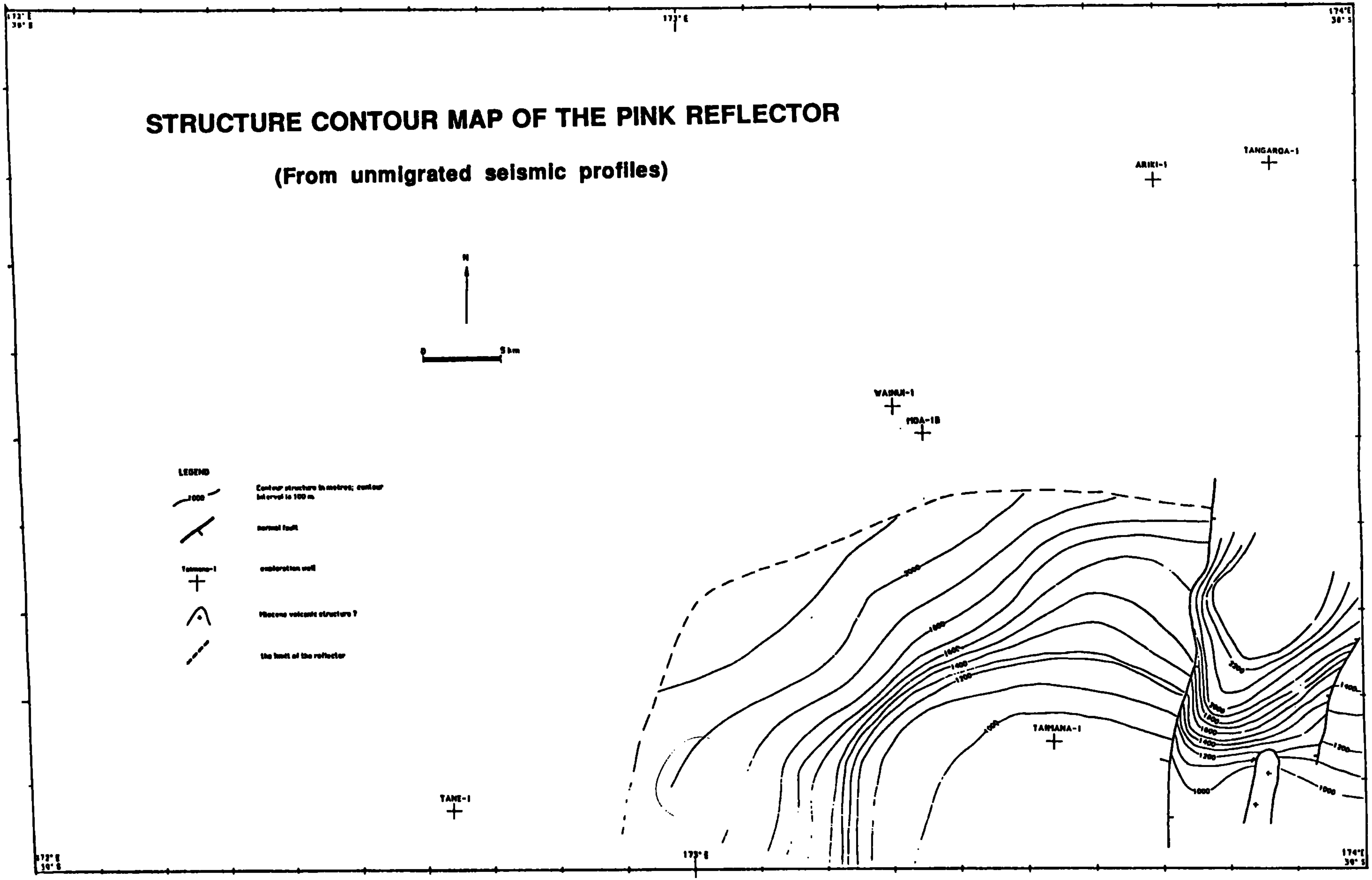


Figure 11: Structure contour map of the pink reflector.

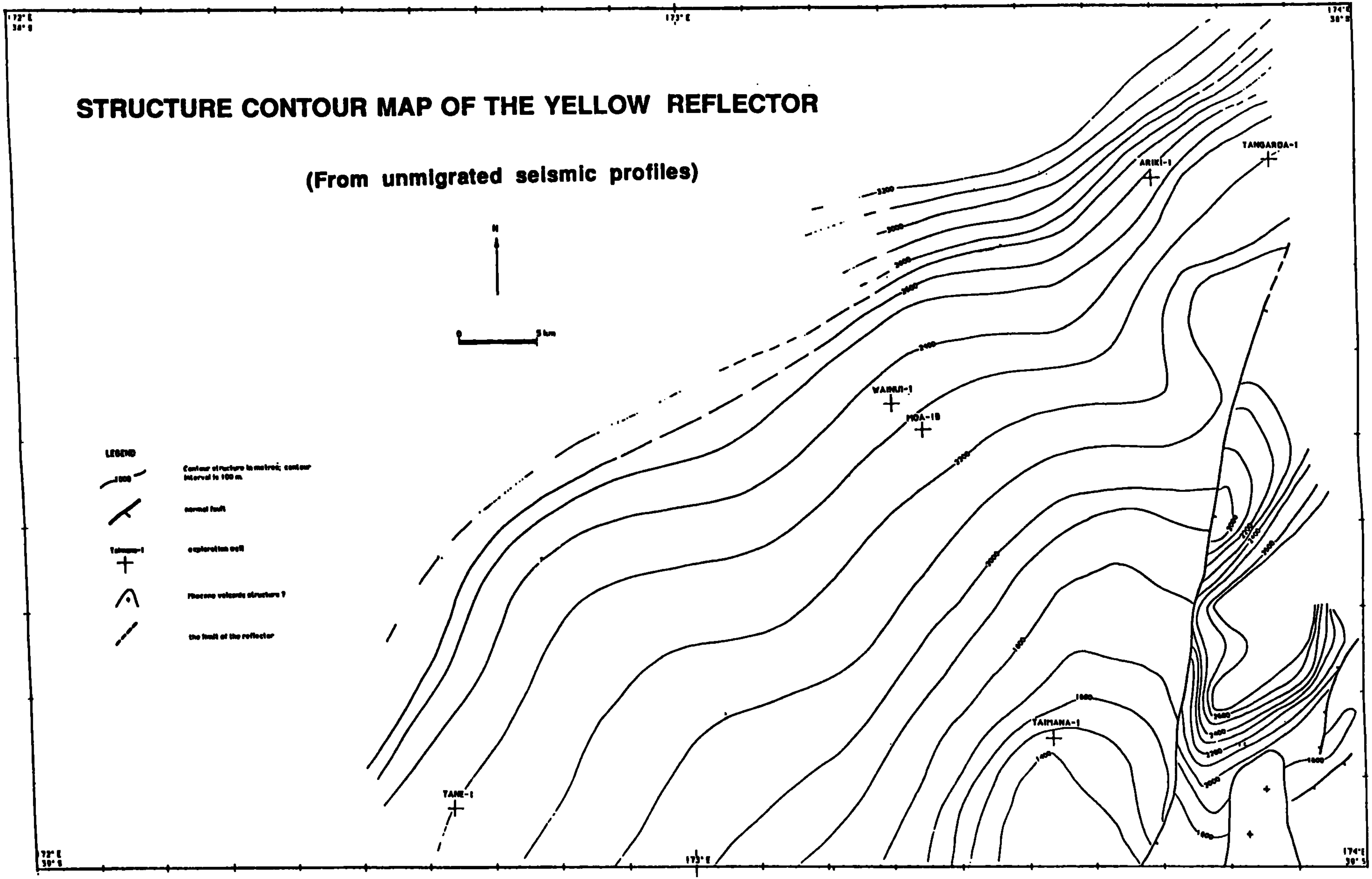


Figure 14: Structure contour map of the yellow reflector.

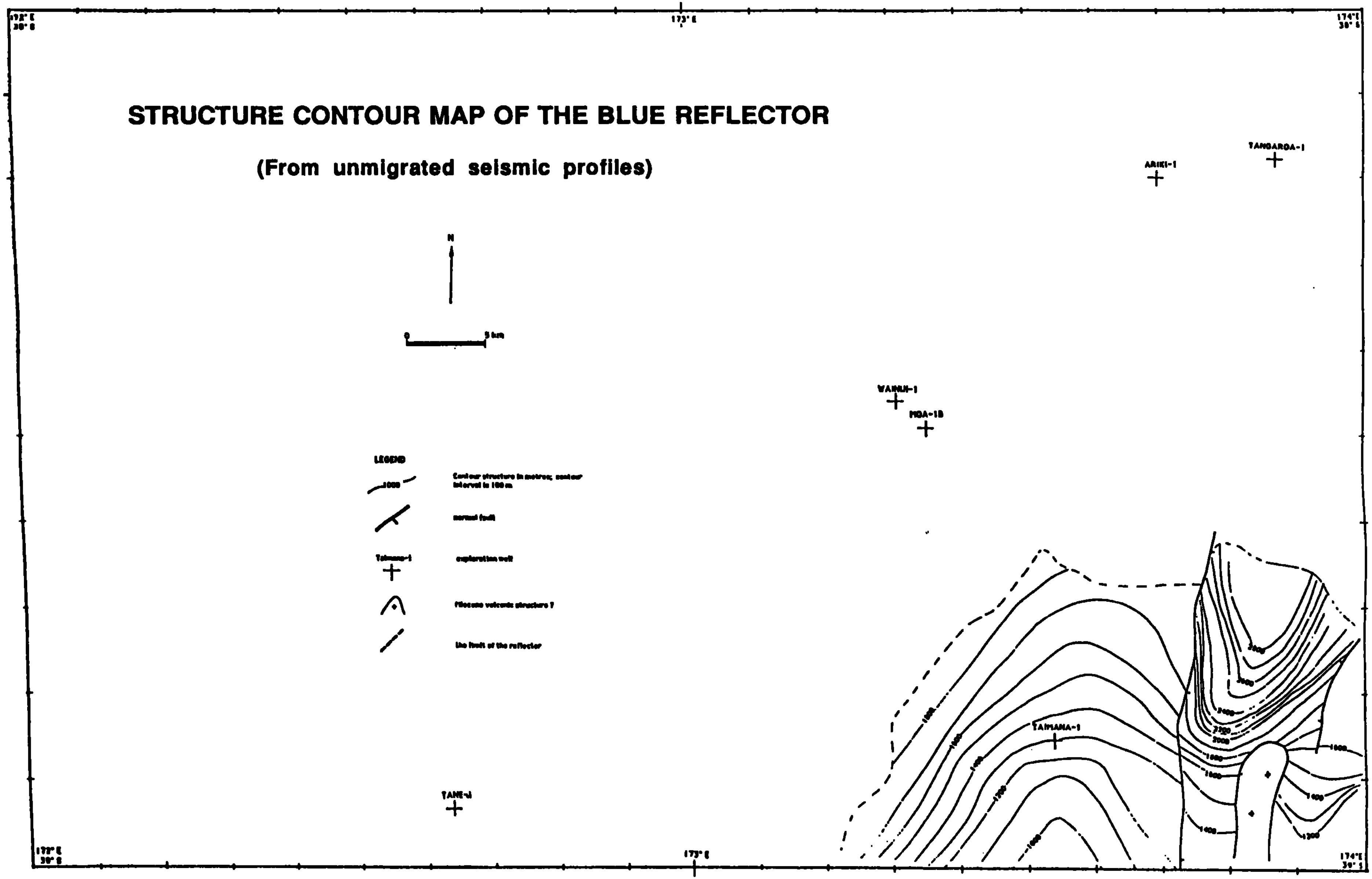


Figure 13: Structure contour map of the blue reflector.

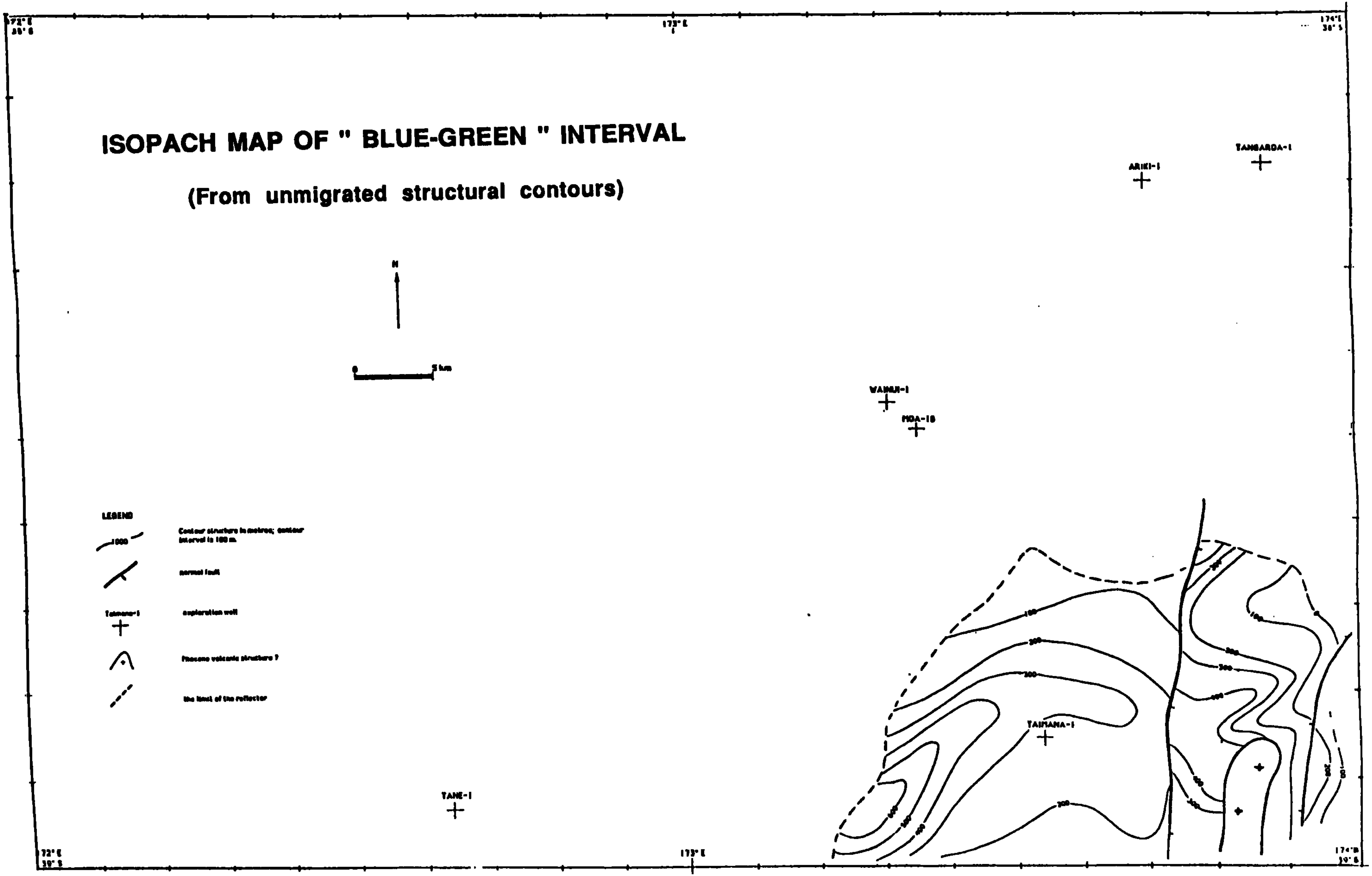


Figure 16: Isopach map of "blue-green".

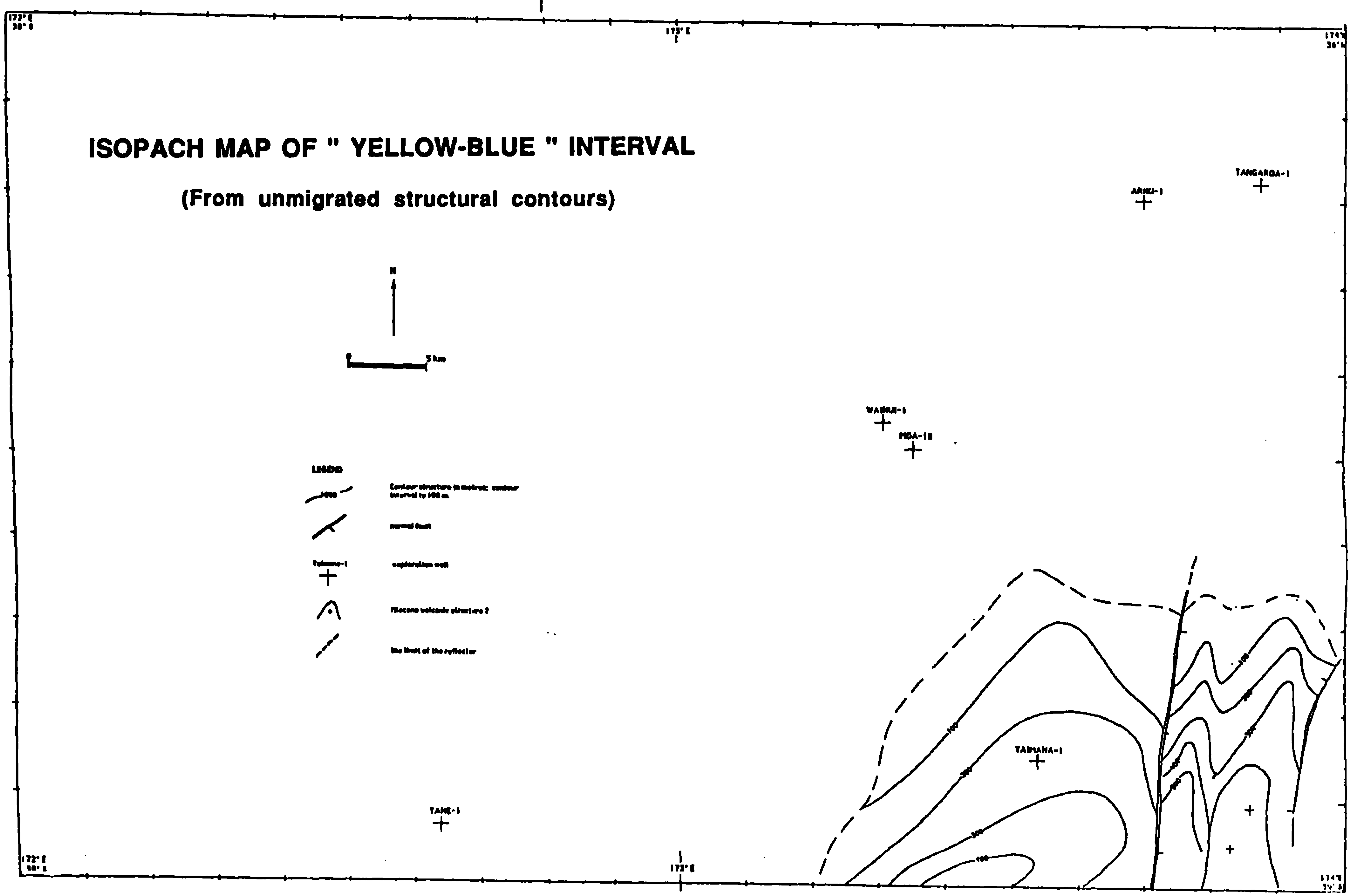


Figure 15: Isopach map of “yellow-blue”.

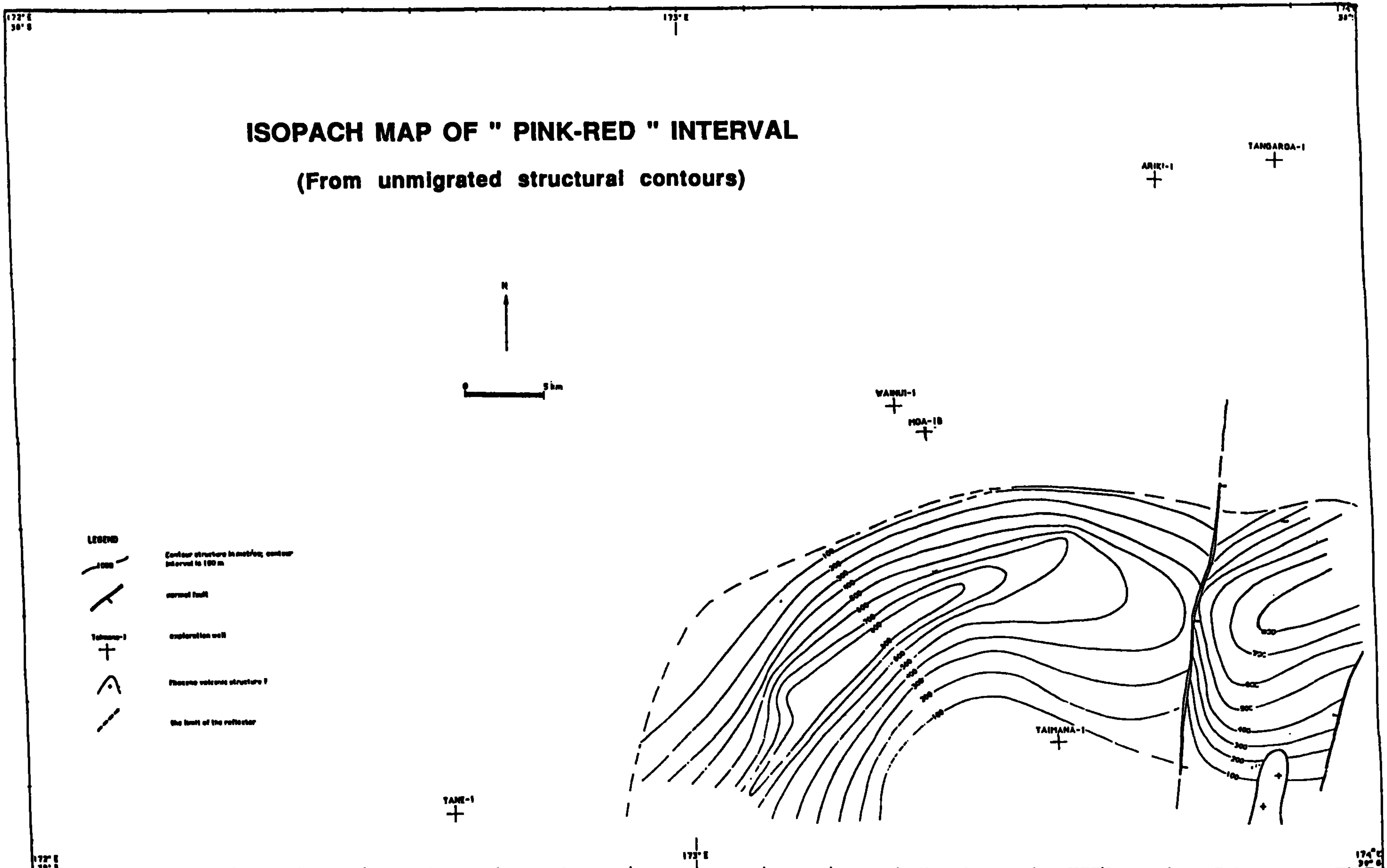


Figure 18: Isopach map of “pink-red”.

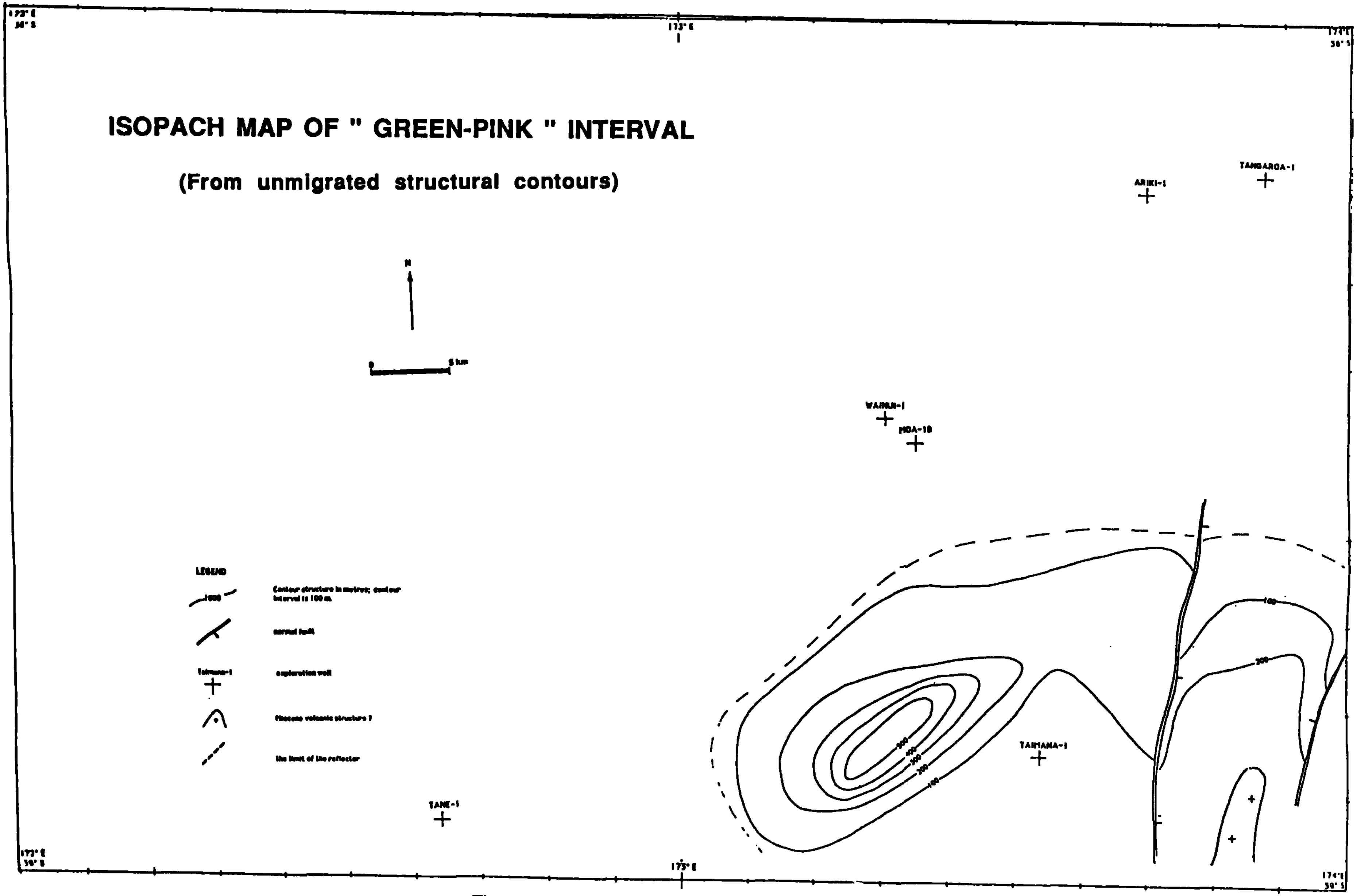


Figure 17: Isopach map of "green-pink".

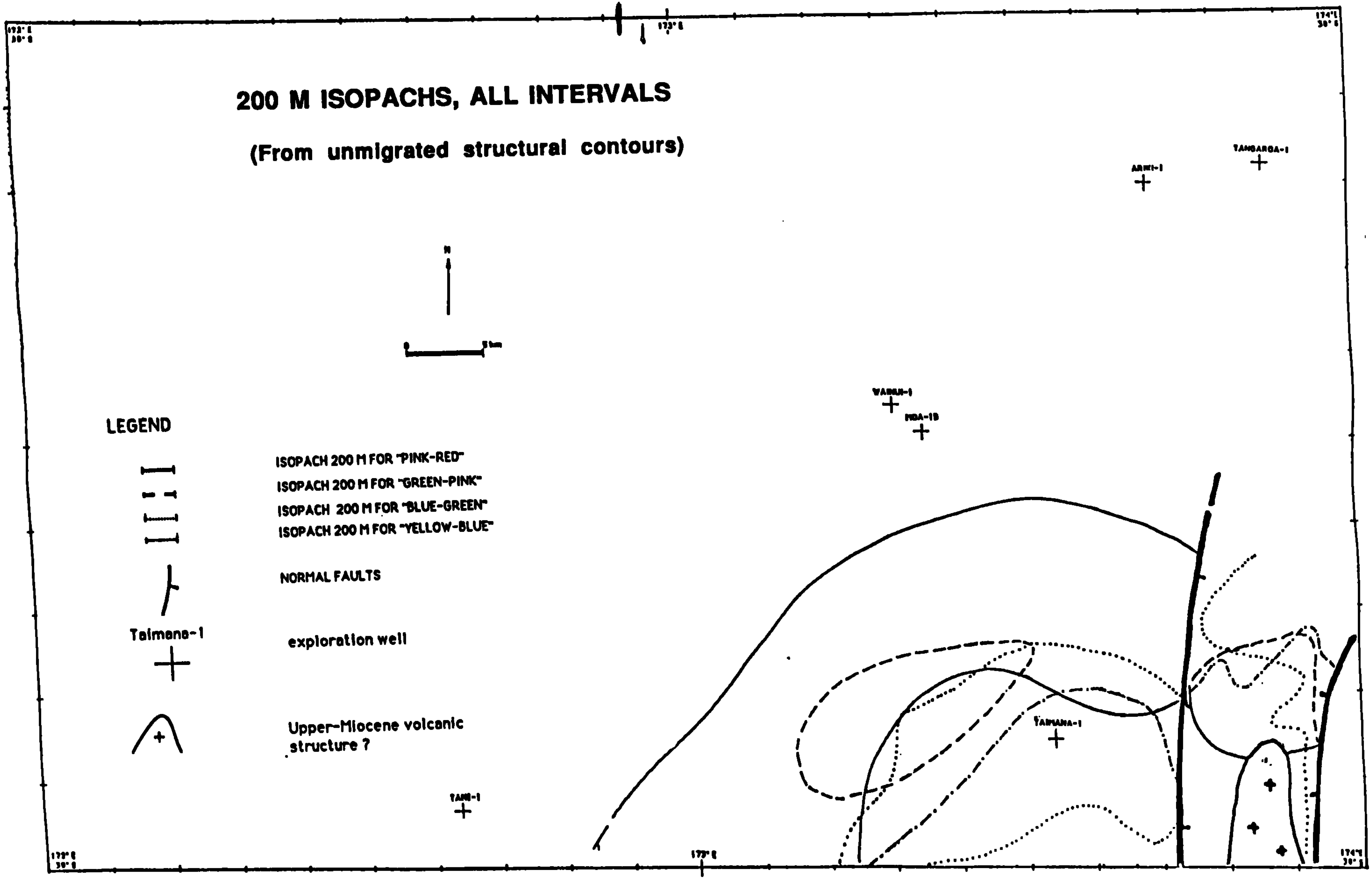


Figure 20: Two hundred metre isopachs, all intervals.

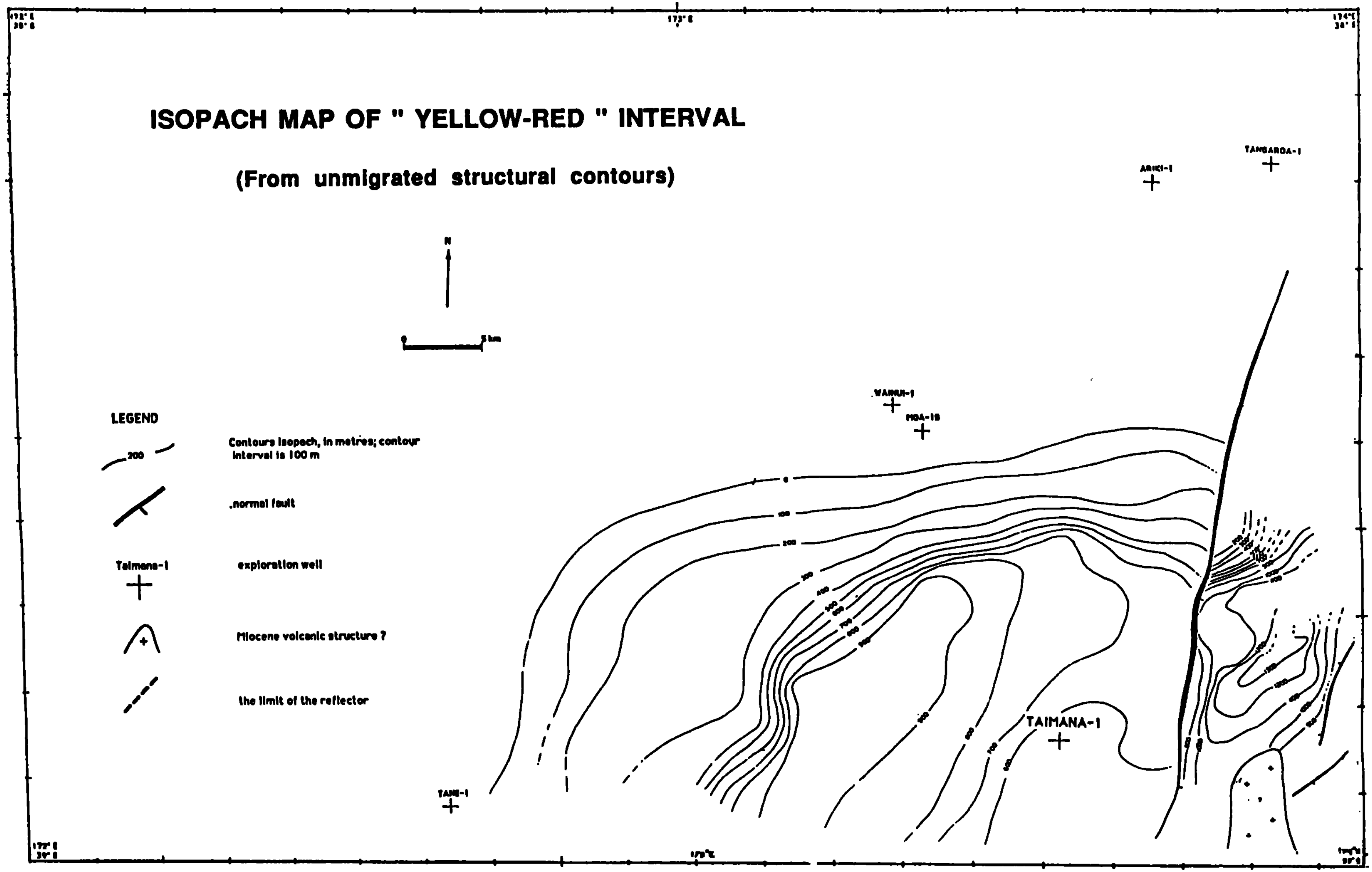


Figure 19: Isopach map of "yellow-red".

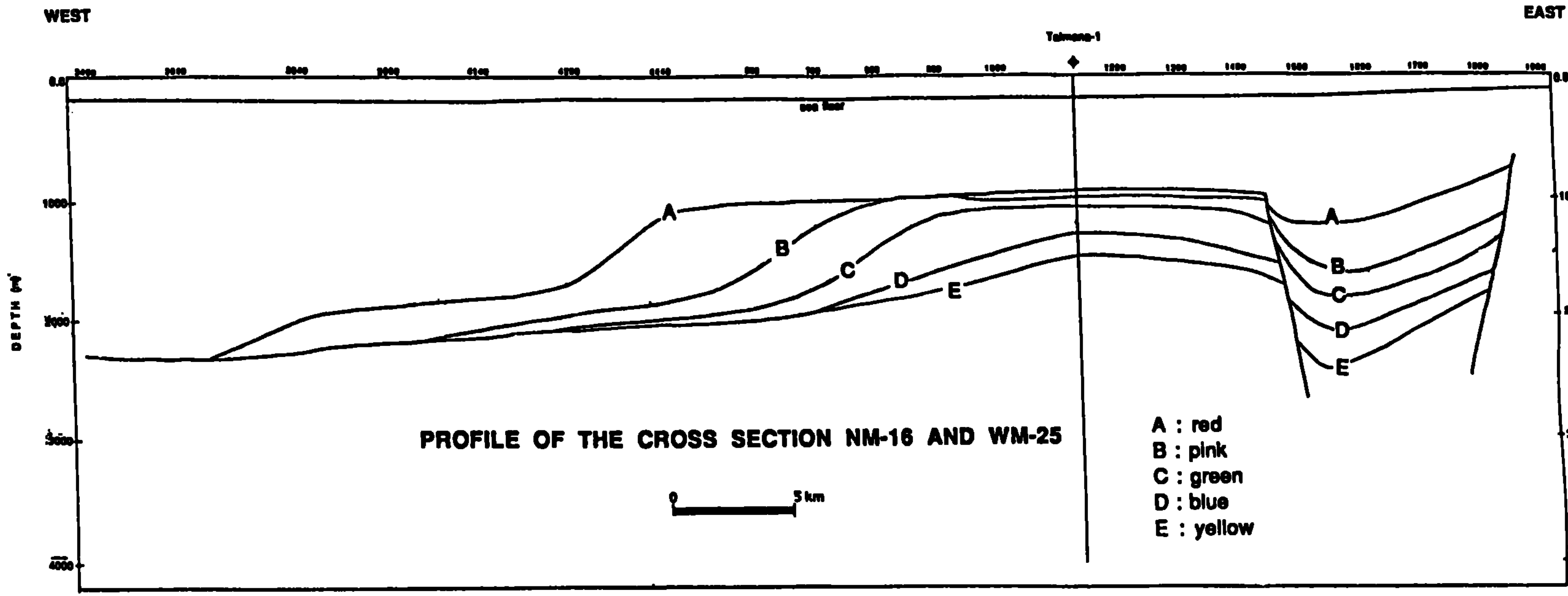


Figure 21: Profile from cross-section, NM-16 & WM-25.

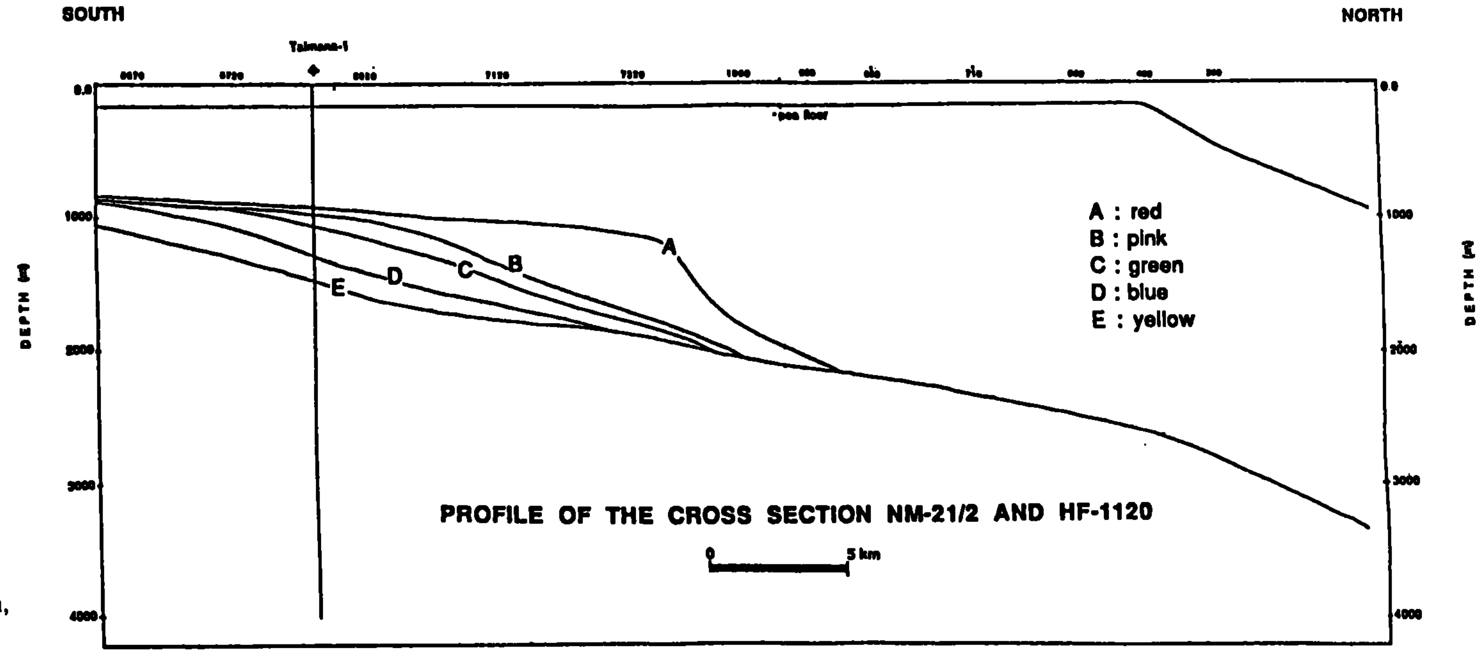


Figure 22: Profile from cross-section, NM-21 & HF-1120.

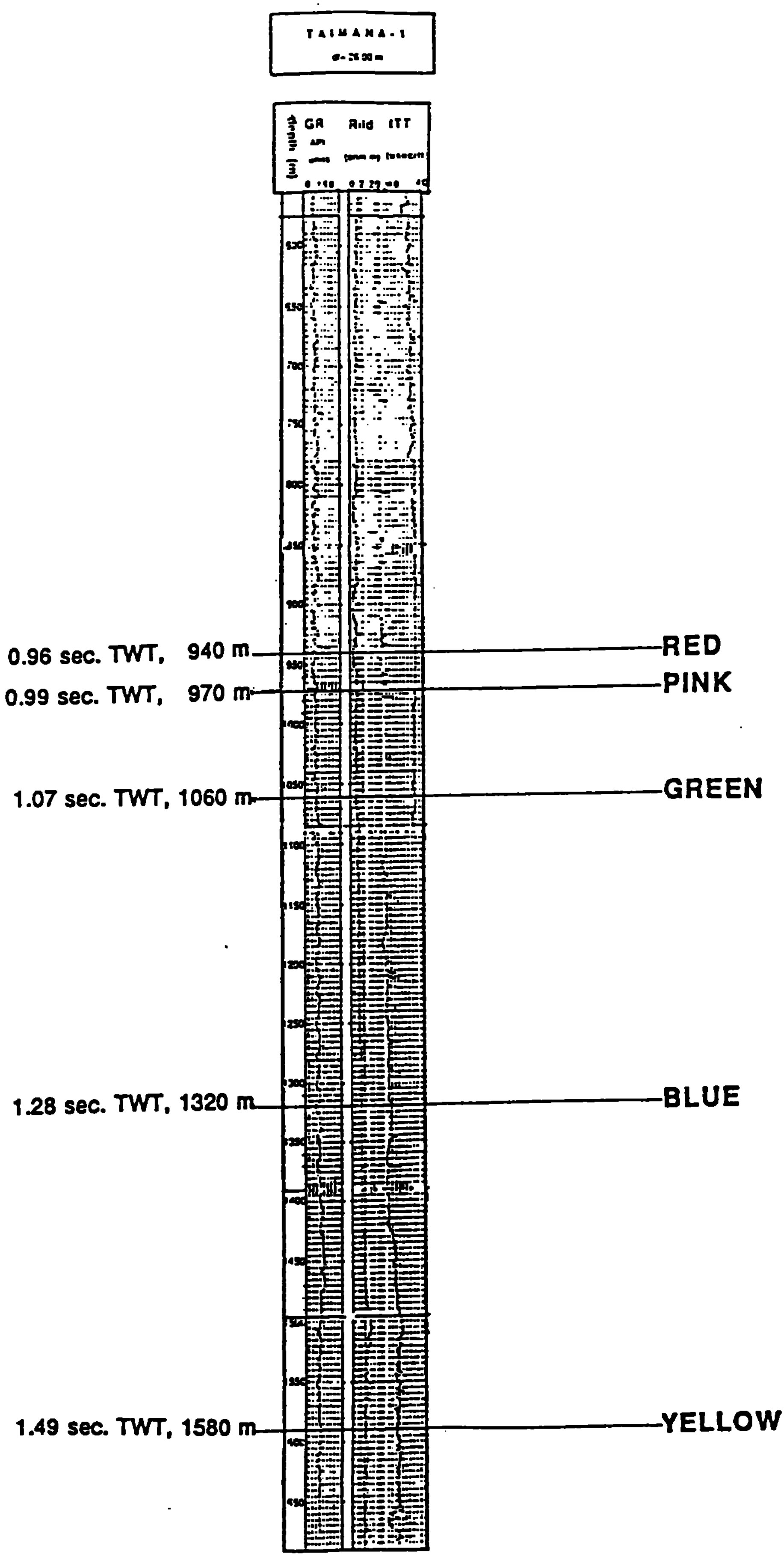


Figure 23: Well log of Taimana-1.

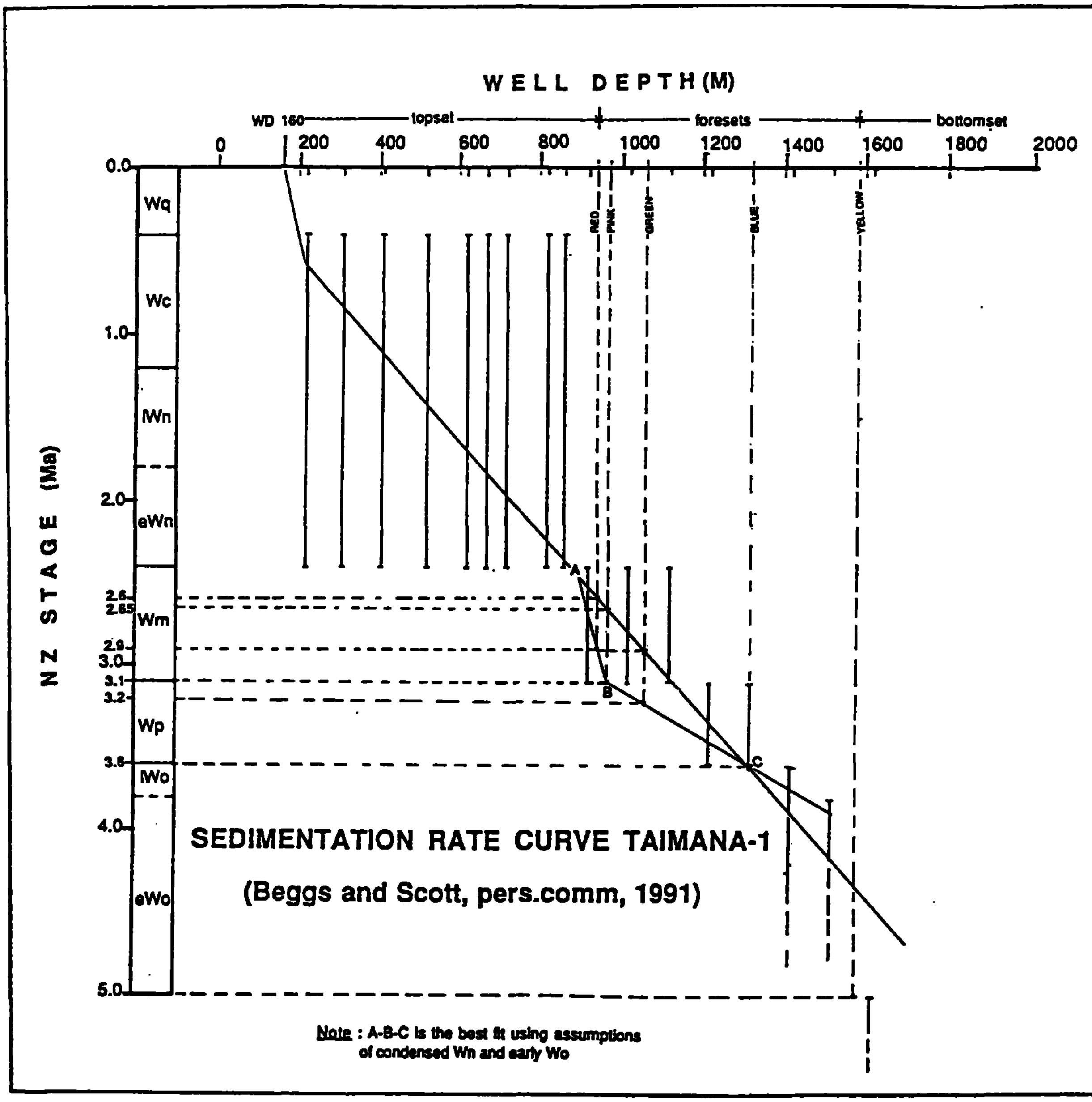


Figure 24: Sedimentation curve of Taimana-1 (Scott and Beggs, pers. comm., 1991).

from early Opoitian to Mangapanian, and that this facies is bounded by low energy deposition sediments (topset and bottomset facies). The termination of the prominent reflectors in the progradational facies (pink, green and blue reflectors) toward their boundaries (red and yellow reflectors) suggests that the latter are unconformities. Onlap seismic-facies units above the red reflector on line WM-23 can be interpreted as channel fills, and the results of the revision of biostratigraphic data from Taimana-1 shows shallowing of the water depth during Opoitian to Nukumaruan. By comparing these features with the model of van Wagoner *et al.* (1988), it can be concluded that the progradational foreset facies bounded by two unconformities is one depositional sequence. In seismic stratigraphic terminology the red reflector is a type 1 sequence boundary, the yellow reflector is a floodplain as well as an unconformity, and the whole of the progradational foresets facies is a "highstand systems tract".

Conclusion

The Giant Foresets Formation in the study area is one part of a big lobe or fan which prograded from the southeast to the northwest. This is demonstrated by the movement of the isopach maxima, which change from a circle in the southeast to an elliptical body to the northwest. The thickness of the progradational foresets facies found in Taimana-1 is 650 m, thickening to 800 m towards the northwest before the red reflector downlaps onto the yellow reflector.

The progradational foresets facies of the Giant Foresets Formation which formed during early Opoitian (5.0 Ma) to Mangapanian (2.6 Ma) is bounded by two unconformities. The features of this facies as clinoforms suggesting that during its development the rate of subsidence was less than the rate of eustatic sea level fall. It is concluded that the progradational facies is one depositional sequence and that this facies is a highstand systems tract, bounded at the top by

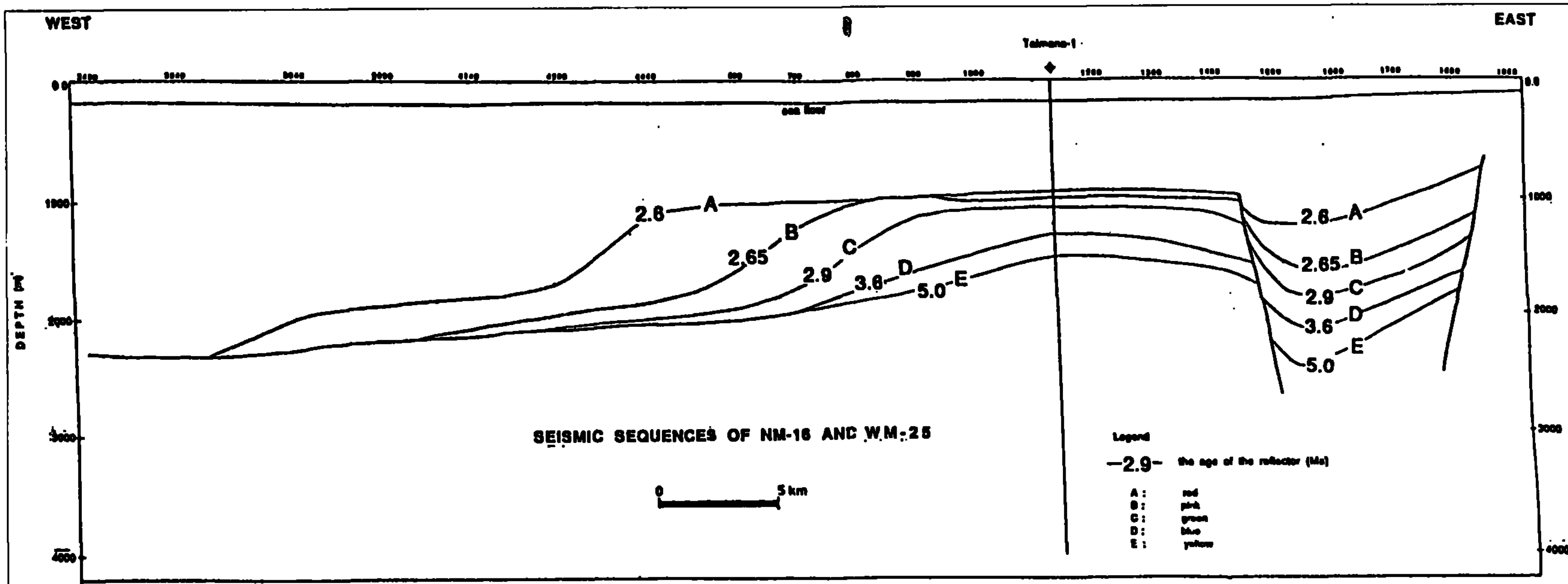


Figure 25: Seismic sequence of NM-16 & WM-25.

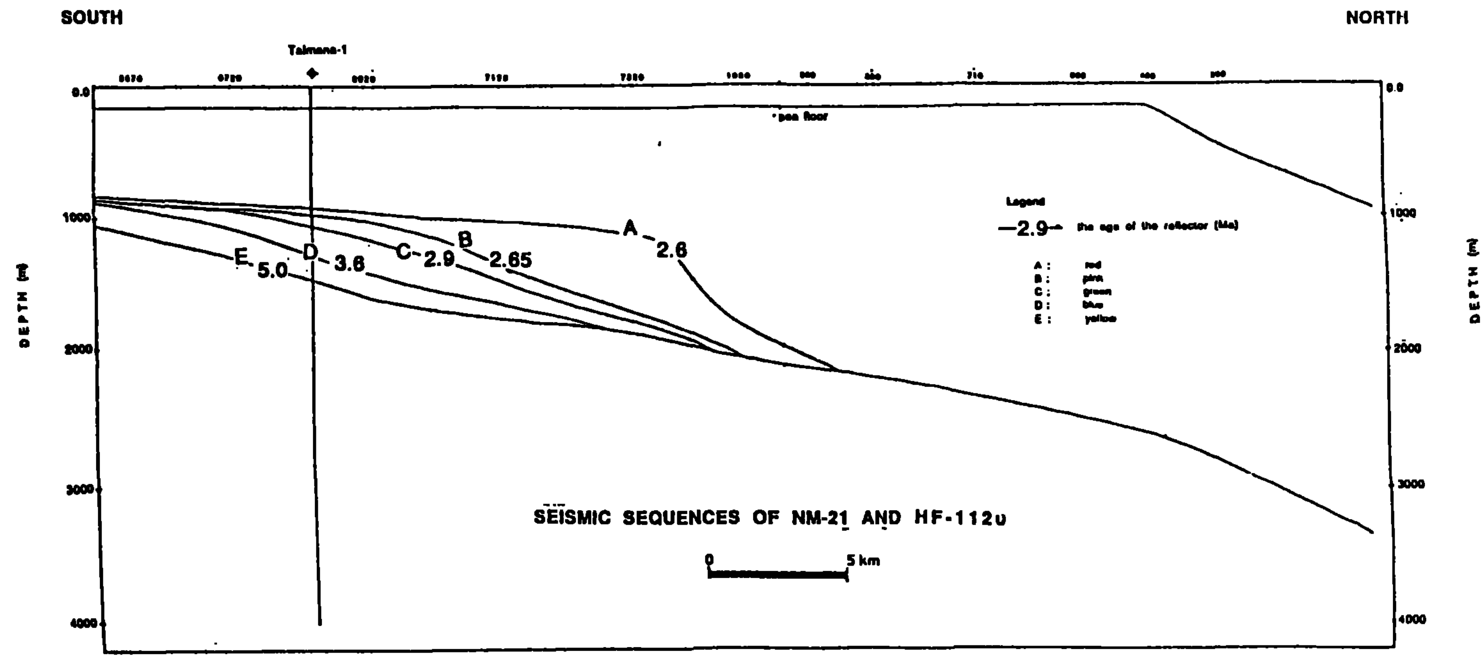


Figure 26. Seismic sequence of NM-21 & HF-1120.

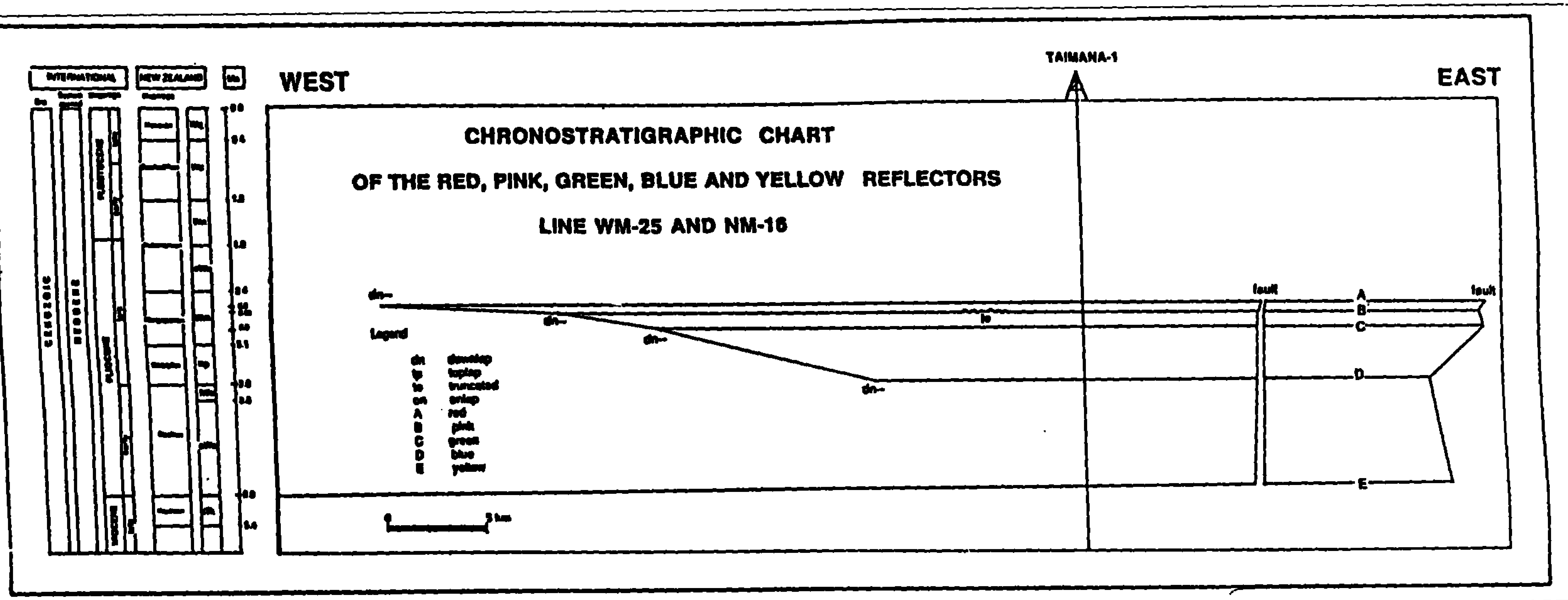


Figure 27: Chronostratigraphic chart of NM-16 & WM-25.

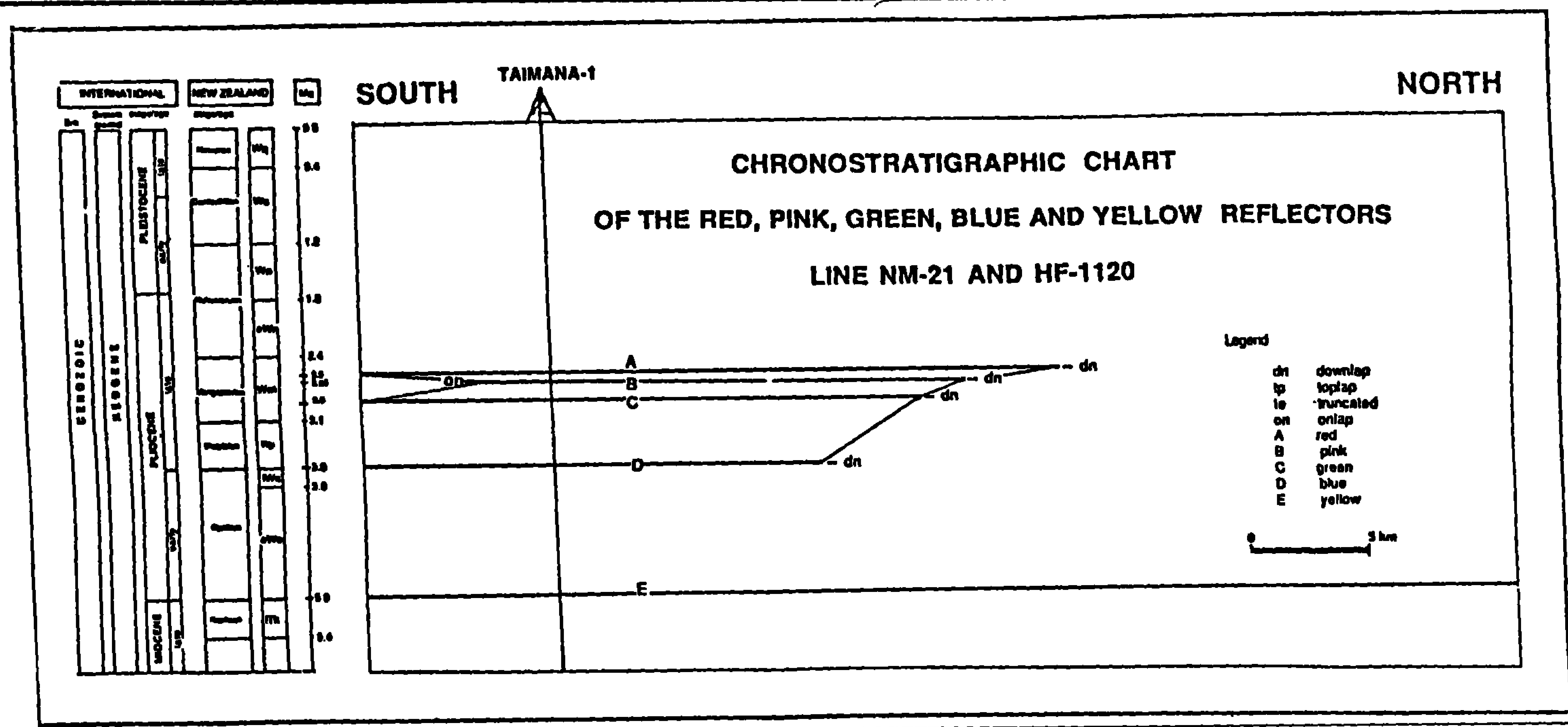


Figure 28. Chronostratigraphic chart of NM-21 & HF-1120.

a 'type 1' sequence boundary and at the bottom by a floodplain. The deposition of the bottomset, progradational/degradational foreset, and topset facies was influenced by the oscillation of sea level from the Upper Miocene to Pleistocene time.

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