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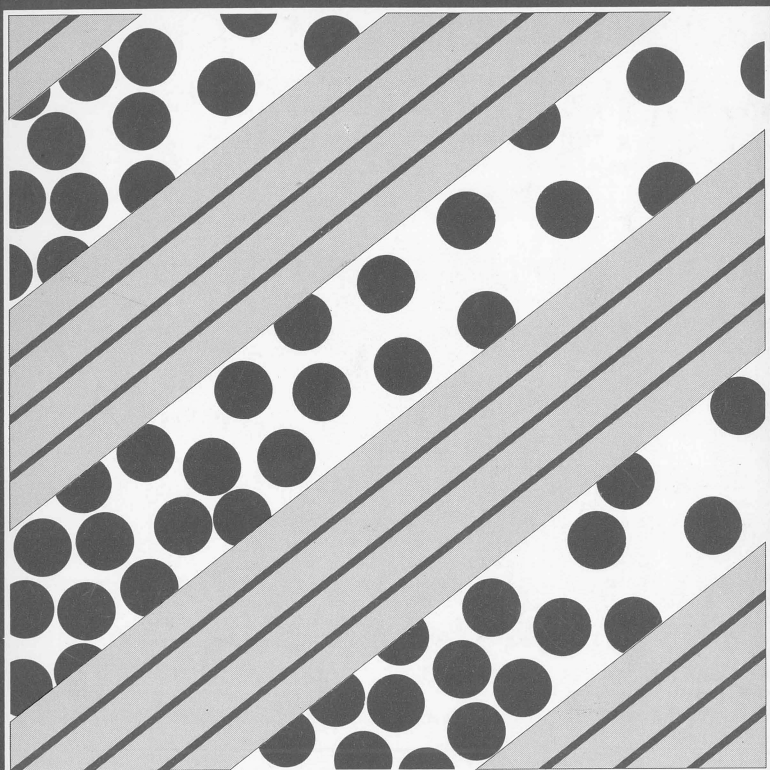

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SEQUENCE STRATIGRAPHIC INTERPRETATION OF SEISMIC DATA IN THE TAROOM REGION, BOWEN AND SURAT BASINS, QUEENSLAND

by

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ABSTRACT
(ATW)

An interpretation of seismic stratigraphic sequences in the Bowen and Surat Basins commenced in a transect covering the Taroom Trough and Comet Ridge in the Taroom region. Thirteen reflectors in the Taroom Trough were selected for mapping on the basis of their continuity and integrity. Using seismic stratigraphic principles it could be demonstrated that at least seven of these reflectors define sequences bounded by regional unconformities. In addition, three reflectors, also identified as sequence boundaries, were recognised near the Comet Ridge on the western margin of the Taroom region. Isopach and structure contour maps were produced for all reflections and intervals using Petroseis^{TM} software. [The isopach and structure contours are expressed in two-way travel time in milliseconds and not as true thicknesses and depths in metres, and hence are referred to as isopach and structure contour maps for convenience.]

Isopachs for the Permian Back Creek and Blackwater Groups generally show a regional easterly increase in sediment thickness, a roughly meridional trend to the isopachs and depocentres commonly developed on the eastern side of the mapped area, so that there is an asymmetrical profile to the preserved sedimentary package. This profile illustrates the strong influence of basement subsidence and structural development on the history of sedimentation. Structural growth and thinning of some units over discrete structures within the mapped area can also be demonstrated.

A similar pattern of isopachs is common to the Permo-Triassic 'Mimosa Supergroup' except that they are strongly modified by erosion as a result of structural growth, uplift and erosion towards the Auburn Arch, combined with thinning of units in this direction.

Isopachs on the Jurassic Surat Basin show the preserved sedimentary succession in the Mimosa Syncline, with the sediments being symmetrically disposed around the south plunging synclinal axis and thinning gradually towards the exposed eroded margins.

The principal structural feature in the study area is the Mimosa Syncline which is well displayed in the Jurassic rocks in outcrop. The syncline is elongated and symmetrical at depth but becomes asymmetrical upwards and the depocentres for individual units have migrated northwards. However, at the base Surat Basin level the syncline is symmetrical and plunges southwards. The depocentre axes mostly occur to the east of the Mimosa Synclinal axis so that folding was independent of the position of the deepest part of the Taroom Trough.

A working model for the tectonic development of the Bowen Basin envisages initiation in the Late Carboniferous -Early Permian in a back arc extensional regime, with subduction well to the east of the Camboon Volcanic Arc. ENE-WSW compression in mid-Permian time caused the onset of foreland loading which accelerated in the Late Permian to late-Early Triassic. During this time there was reactivation of earlier extensional related structures. Late Triassic erosion was followed by Jurassic Surat Basin deposition in a gently subsiding intracratonic sag.

Seismic surveys along the eastern margin of

the Bowen Basin indicate differing structural styles and change in character along strike. The eastern margin of the Bowen Basin in the Taroom area shows strong tilting of the sediments beneath the Surat Basin sediments and a monoclinal fold dominates the structure. Foreland loading in the Late Permian to late-Early or Middle Triassic with subsidence driven by thrust faults is a suggested mechanism for the late tectonic development of this region. Duplexing of the basement to the east is implied with west directed thrusting. Maximum subsidence occurred adjacent to the thrust sheets where the load was greatest. The western limb of the Mimosa Syncline probably resulted from depositional dips that was little modified by tectonism, whereas the steeper eastern limb was produced by thrusting on the eastern margin.

Tectonic subsidence curves for the Taroom area all have a consistent pattern showing four main stages of structural development: 1. early thermally-driven subsidence, 2. rapid subsidence with a sedimentary pile greater than 7 km thick in the Taroom Trough, 3. a period of non-deposition and erosion represented by the unconformity at the base of the Surat Basin, 4. finally, slow subsidence probably caused by thermal relaxation. It is estimated that it took about 10 Ma for the effects of thrusting to be propagated 100 km to the west.

INTRODUCTION
(ATW)

PROJECT BACKGROUND

The Sedimentary Basins of Eastern Australia (SBEA) Project is a multidisciplinary study of the Bowen, Surat and Gunnedah Basins. It is part of the National Geoscience Mapping Accord and is a collaborative Project between the Bureau of Mineral Resources (BMR), Geological Survey of Queensland (Department of Resource Industries) and New South Wales Department of Mineral Resources (Geological Survey and Coal & Petroleum Geology Branches), with co-operation from CSIRO, universities and industry.

Although the Bowen, Surat and Gunnedah Basins have considerable resource potential and there have been both regional and local studies of the basin system, there are still uncertainties as to their precise geometry, mode of formation, the relationship of basin development to tectonic events in neighbouring orogenic zones, and the control exerted by these events on the timing of the generation and accumulation of hydrocarbons. In addition, a rationalisation and refinement of the information on dating the sediments is required, in particular, an improvement in the precision of dating and correlation of the sedimentary packages.

OBJECTIVES

The aim of the project is to undertake an integrated basin analysis with emphasis on sedimentary, structural, tectonic and thermal histories of the sedimentary basins in order to assess the economic potential for hydrocarbons in the basins. The strategies applied to achieve the objectives of the project are:

1. Determine the spatial and temporal distribution of the various sedimentary packages as an aid towards understanding the distribution and nature of hydrocarbon resources.

2. Determine the structural geometry, evolution and tectonic setting of the sedimentary packages.

3. Determine the maturation and burial history.

4. Provide an integrated geological history of the basin system.

The purpose of this report is to record the initial results of the first phase of a regional seismic synthesis, using the principles of sequence stratigraphy in the interpretation and integration of industry and BMR seismic data in the Taroom region of the Bowen and Surat Basins (Fig. 1).

TECHNIQUES AND METHODOLOGY

A network of industry seismic lines was selected to provide a regional coverage, with approximately 10 km line spacing where possible (Fig. 2). Preference was placed on the more recent multifold seismic surveys, but in some areas only early single fold data were available. Interpretation of the industry seismic lines commenced in the Taroom- Mundubbera Sheet areas in the northeastern corner of the Surat Basin (Fig. 1) where a very thick succession of Permian and Triassic

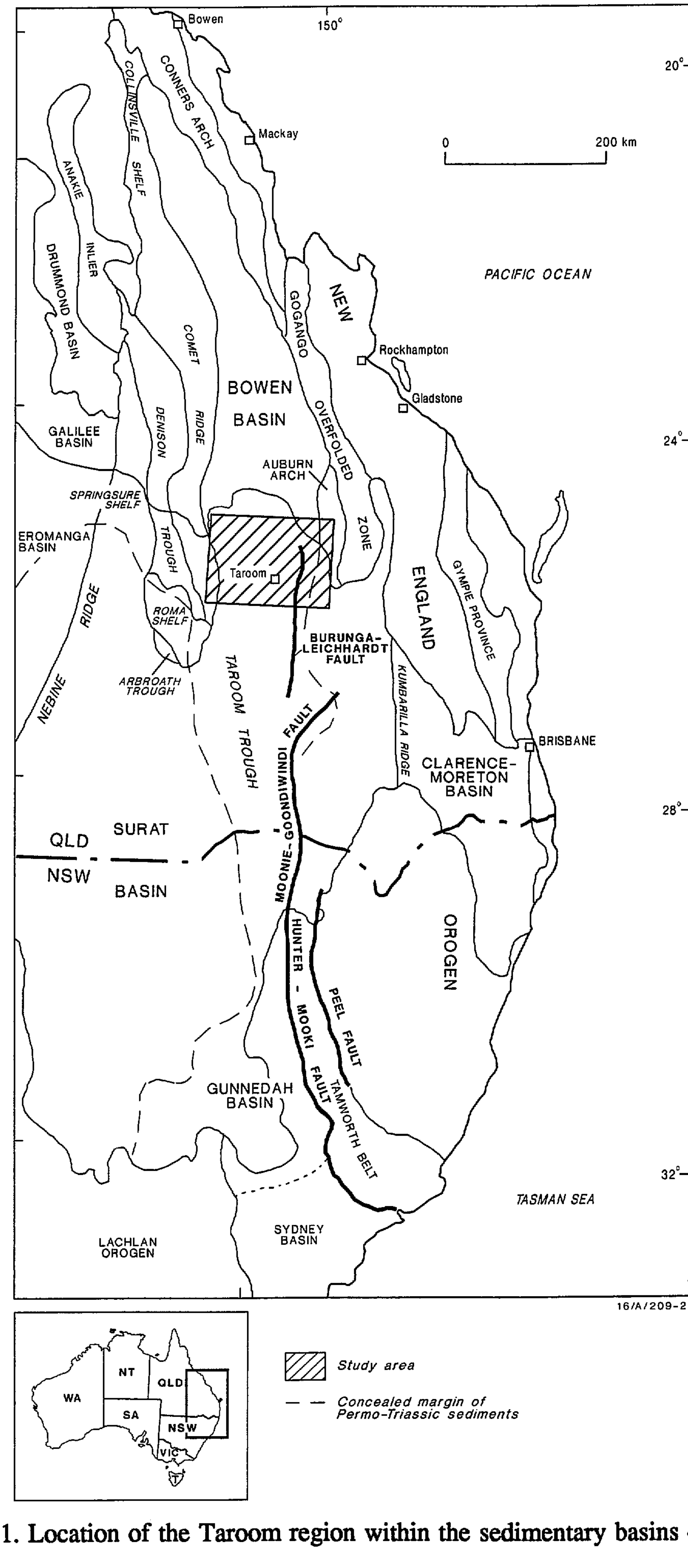


Fig. 1. Location of the Taroom region within the sedimentary basins of eastern Australia.

sediments is preserved beneath a comparatively thin succession of Jurassic sediments. We refer here to this area, shown in full on Figure 2, as the Taroom region. The principles of sequence stratigraphy (for example, Vail & others, 1977a, 1977b; Mitchum, 1977; Van Wagoner & others, 1988, 1990) were applied to the interpretation of the seismic sections, as outlined in the section on Sequence Boundaries and Sequences.

The formation boundaries and sequence boundaries were colour coded on paper copies of the seismic sections and the presence of stratal terminations, truncations, onlap, offlap and similar features related to these boundaries were marked and tabulated onto data record sheets where applicable. A standard pro forma was used to record the data obtained. The relationship of the seismic reflectors to the established stratigraphy, as determined from well log and outcrop correlation, was referenced to a stratigraphic table relating to the Taroom Trough (Fig. 3).

In addition to the characteristics of sequence boundaries, any stratal patterns and intra-sequence formation patterns discernible on the seismic line were noted. Well ties were made using standard graphic logs with well depths converted to two-way time (TWT) using rms velocities. In the longer term, when digitised sonic log data are available, synthetic seismograms will be used to confirm well ties. The seismic sequence and formation boundaries were tied around closed loops wherever possible.

After completion of the interpretation, verification of the closures around loop ties, correlating the selected seismic reflectors with wells and recording the data, the sequence and formation boundaries on the interpreted lines were digitised and processed in the Petroseis™ seismic data processing package. Using this system, two-way travel time isopach and structure contours, cross sections and isometric diagrams of the network of industry seismic were produced. The PEP™ system will be used to process digital wireline log data for the production of synthetic seismograms and the display of well log correlations and graphic log displays. Digitised sonic log data are being processed by the Geological Survey of Queensland.

Most of the maps that form the basis for this Record are not reproduced here, but are listed in Appendix 1 and can be obtained separately at a scale of 1:250 000 from the BMR Sales Centre. The maps can be examined in the BMR by arrangement with R.J. Korsch or A.T. Wells. A digital database including shot point and horizon data for all interpreted lines or any combination of lines and horizon data is also available (see Appendix 2).

Although we refer to the maps as isopach maps or structure contour maps for convenience, they have been compiled from seismic two-way travel time data in milliseconds and have not been converted to depth or thickness in metres.

Nomenclature

An explanation of the nomenclature employed in this report for some of the commonly used basin terms is deemed necessary to avoid any confusion. The two most commonly used terms in the Bowen Basin and Surat Basin to describe the disposition, geometry and historical geology of the sedimentary fill are the Taroom Trough and the Mimosa Syncline. The term Taroom Trough is used in this report to define the limits of the depositional basin in which the thickest sediments were deposited, that is, the area encompassing the depocentres. Whilst it may be difficult to precisely define the boundaries between

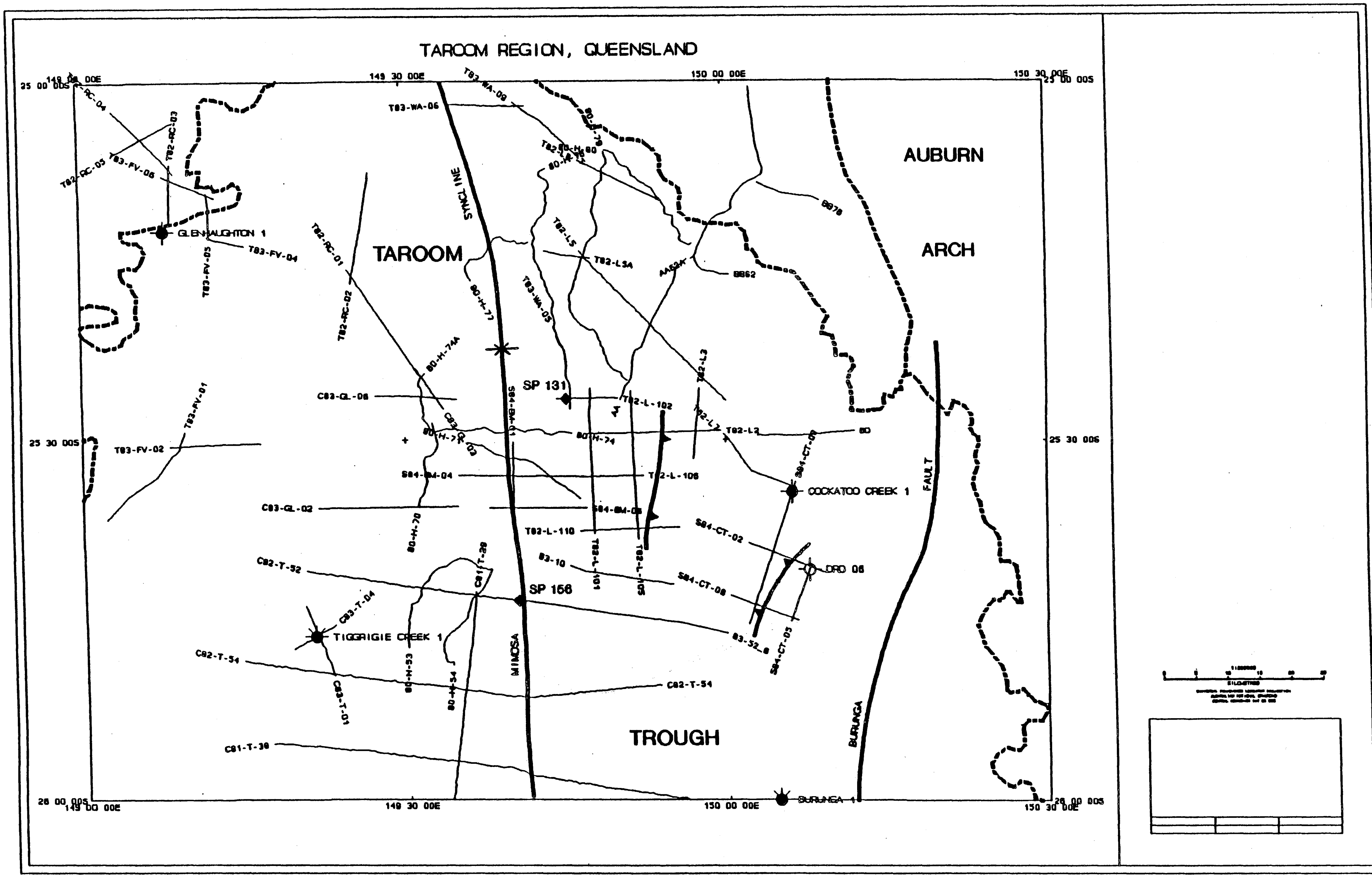


Fig. 2. Map showing main structural features and locations of seismic lines in the Taroom region that form the regional network for interpretation in this study. Also shown are the relevant petroleum exploration wells (filled circles) and the two shotpoint localities (filled diamonds) for which subsidence curves were constructed.

TAROOM REGION

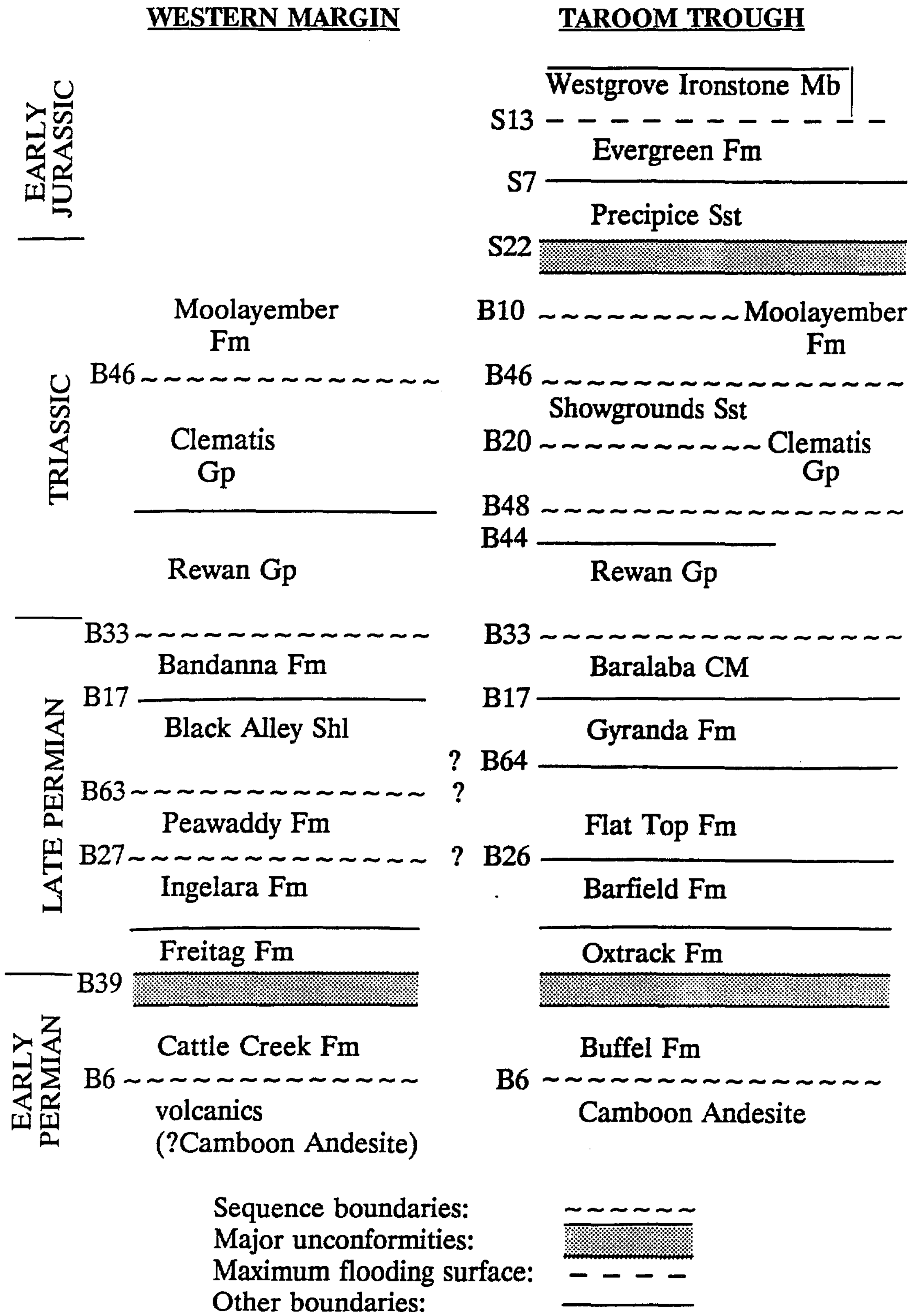


Fig. 3: Stratigraphy of the Taroom region, showing the positions of sequence boundaries, unconformities, and other reflectors (indicated by code numbers). The relative positions of B63 and B64 are after Foster's (1982) study, although this is currently under review, and the two horizons may be time equivalent. The correlation of B27 and B26 follows Parfrey's (1988) work, but the correspondence may not be exact. The matching of the sub-Freitag and sub-Oxtrack unconformities is after Brakel & Totterdell (in press).

the Taroom Trough and neighbouring Comet Ridge and Auburn Arch, it nevertheless follows that the axis defining the greatest thickness of sediments in the basins must be coincident with the axis of the Taroom Trough. The term Mimosa Syncline is used for the structural feature that postdates deposition in the Bowen Basin and was caused by deformation of probable Late Triassic age. Its geometry was possibly enhanced during subsidence associated with deposition of the Surat Basin and/or during deformation after deposition ceased. The syncline is well illustrated chiefly by the fold, so clearly displayed in the outcrop of the sedimentary succession in the Surat Basin in the Taroom region.

WORK PROGRAM

The work program of sequence stratigraphic interpretation in the Sedimentary basins of eastern Australia Project is designed so that a series of latitudinal transects across the Bowen, Surat and Gunnedah Basins are systematically interpreted, and contour maps and three dimensional displays of the data prepared.

This Record details the results from the major part of the first transect which runs across the northeastern part of the Surat Basin, and underlying and cropping out Bowen Basin, in the Taroom region. A multifold line across the axis of the Taroom Trough was the starting point for selecting and defining prominent reflections and testing their continuity across the study area transect. Initially, reflections were picked for their continuity and integrity, and tested using seismic stratigraphic principles (see references above) to determine sequence boundaries; no attention was paid, in the first instance, to the lithostratigraphy. A corollary is that possibly some sequence boundaries are not represented by strong reflectors. After the horizons were selected for interpretation, attempts were made to correlate them with exploration wells and identify their position relative to lithostratigraphic contacts. Well control on the eastern part of the Sheet area is sparse and identification of the reflection events relies largely on correlation with three deep wells - UOD Cockatoo Creek 1, COE Tiggrigie Creek 1 and MPA Glenhaughton 1, and one shallow stratigraphic bore, GSQ DRD 6. Initially, identification of the Triassic reflectors depended on an approximate projection to formation boundaries in outcrop on the eastern edge of the Bowen Basin to the north of the interpreted transect, in the Baralaba Sheet area. The tie with the Tiggrigie Creek 1 well gave a more definitive identification of the reflectors in the Triassic succession although there are still significant gaps in the line ties to the south. Direct line ties from east to west along the transect are not possible because the few seismic lines shot on the Comet Ridge are isolated from the more dense coverage over the Taroom and Denison Troughs on either side.

The analysis of the network industry seismic lines will continue westwards into the Denison Trough to complete the latitudinal transect. From here a tie will be made with seismic line BMR78.06 to the north completing the network of industry seismic lines on the Baralaba, Springsure, Duaringa and Emerald 1:250 000 Sheet areas. From this point the interpretation coverage will continue to the south, progressing in latitudinal transects until the regional seismic coverage of the Bowen-Surat and Gunnedah Basins is completed.

GEOLOGICAL SETTING OF THE BOWEN AND SURAT BASINS (JMT)

INTRODUCTION

The Permo-Triassic Bowen Basin and the overlying Jurassic-Cretaceous Surat Basin are located in eastern Queensland and northern New South Wales (Fig. 1). The Bowen Basin is the northernmost part of the Sydney-Gunnedah-Bowen basin system. The basin contains up to 10 km of terrestrial and shallow marine, largely clastic sediments, and has substantial deposits of black coal. The thickest successions are found in the Taroom and Denison Troughs, which are separated by the Comet Ridge. Figure 3 shows the generalised stratigraphy of the Bowen and Surat basins in the study area, as well as the correlation between the Taroom Trough succession and the section intersected in the Glenhaughton 1 well on the Comet Ridge which has been interpreted in terms of Denison Trough nomenclature. Outcrops of the Bowen Basin extend from the Collinsville area in the north, south to approximately 25°S, where they are unconformably overlain by sedimentary rocks of the Surat Basin. The Bowen Basin succession continues in the subsurface beneath the Surat Basin southwards into New South Wales, where it is contiguous with the Gunnedah Basin. During its development, the Bowen Basin was bounded to the east by a continental margin volcanic arc and an active orogenic belt of the New England Orogen, and to the west by a relatively stable craton of Early to Middle Palaeozoic rocks.

The Surat Basin is continuous with the Eromanga Basin across the Nebine Ridge in the west, and with the Clarence-Moreton Basin across the Kumbarilla Ridge in the east. The basin extends well into New South Wales where it unconformably overlies the Gunnedah Basin and parts of the Lachlan Orogen. The Surat Basin succession consists of up to 2500 m of generally flat-lying, clastic sedimentary rocks that were deposited in fluvio-lacustrine to shallow marine environments. Sedimentary rocks of the Surat Basin are more widespread than those of the Bowen Basin, although the greatest sediment thickness approximately coincides with the axis of the underlying Taroom Trough.

GEOLOGICAL DEVELOPMENT

The Bowen Basin was initiated in the latest Carboniferous or Early Permian due to back-arc extension associated with subduction along a continental margin volcanic arc (Camboon Volcanic Arc). This extension led to the development of a series of half-graben in the western part of the basin (Denison Trough); small half-graben have also been recognised at the base of the Taroom Trough succession (Elliott & Brown, 1988), and in the westernmost part of the Taroom Trough, south of the Denison Trough (Cosgrove & Mogg, 1985). Initial Early Permian sedimentation was confined to these structures. In the Denison Trough, quartzose clastics and coal were deposited in fluvial, lacustrine and deltaic environments (Reids Dome beds). Similar sediments were deposited in other half-graben such as the Arbroath Trough to the south. Following the extensional phase, the basin underwent regional sag. Although sedimentation was initially restricted to the half-graben, a marine transgression subsequently covered much of the basin. Mixed carbonate and siliciclastic sedimentation occurred in the Taroom

Trough (Buffel Formation and equivalents), while in the west, the fine-grained clastic rocks of the Cattle Creek Formation were deposited. Uplift on the basin margins led to the influx of coarse, quartzose sediments as deltas prograded into the basin from the west (Aldebaran Sandstone). Structural instability is reflected in unconformities within both the Cattle Creek Formation and Aldebaran Sandstone. This phase of deformation was again followed by a period of basinal sag. The subsequent marine transgression saw the deposition of deltaic-shallow marine sediments throughout much of the basin. The sediments of the Cattle Creek Formation-Catherine Sandstone interval in the Denison Trough are quartzose, indicating derivation from the craton to the west. Equivalent sediments on the eastern side of the basin are more lithic and were probably derived from the inactive volcanic arc. Volcanolithic sediments in the Peawaddy and Flat Top Formations, together with the occurrence of air-fall tuffs, indicate tectonic activity in the orogen to the east and the onset of foreland basin conditions (Fielding & others, 1990). During the Late Permian, sediments shed from the orogen accumulated in alluvial plain, deltaic and paralic environments to form the extensive coal measures of the Blackwater Group and equivalents. Beginning in the latest Permian, the basin underwent a period of compression and partial inversion, which culminated in the Middle Triassic. Deposition of fluvial sediments, including red-beds, began in the latest Permian (Foster, 1983) and continued into the Middle Triassic. The ongoing deformation is reflected within the Triassic succession by the presence of alluvial fan sediments and unconformities of both local and regional extent. Deformation culminated in the Middle or early Late Triassic and deposition ceased in the basin. Up to 3000 m of sediment was eroded from its tilted eastern margin.

Surat Basin sedimentation commenced in the Early Jurassic with the deposition of the fluvial Precipice Sandstone. Fluvial and fluvio-lacustrine conditions, with some marine influence during deposition of the Evergreen Formation, prevailed until the Early Cretaceous. A basinwide marine transgression in the Early Cretaceous led to the deposition of coastal plain-marine shelf sediments of the Bungil Formation and Rolling Downs Group. Deposition was controlled by slow subsidence, with intermittent deformation due to movement on pre-existing faults.

TECTONIC SETTING

The Bowen Basin forms the northernmost section of the larger Sydney-Gunnedah-Bowen basin system (Fig. 1). The basin contains two main depositional areas, the NNW-SSE trending Taroom and Denison Troughs, which are separated by the Comet Ridge. The troughs are bounded in the west by the Anakie Inlier and Drummond Basin, and the Collinsville, Springsure and Roma shelves, and in the east by the Gogango Overfolded Zone and the Connors and Auburn Arches. The Taroom Trough is an asymmetric, near-meridional trough that extends from Collinsville in the north to the Gunnedah Basin in NSW. The eastern boundary of the Taroom Trough is defined by the Burunga-Leichhardt-Moonie-Goondiwindi-Mooki fault system. An intensely deformed region in the northeastern part of the Taroom Trough, east of the Comet Platform, is termed the Dawson Fold Zone.

Several models have been proposed for the tectonic and structural evolution of the Bowen Basin. A widely accepted model for the origin of the Sydney-Gunnedah-Bowen Basin system is that it is a foreland basin to the New England Orogen (see, for example, Murray, 1985; Fielding & others, 1990).

However, a number of workers (Scheibner, 1973; Harrington, 1982; Korsch, 1982; Harrington & Korsch, 1985; Ziolkowski & Taylor, 1985; Hammond, 1987; Mallett & others, 1988; Murray, 1990) have argued that the Sydney-Gunnedah-Bowen basin system had an extensional or transtensional origin. Korsch & others (1988, 1990b) suggested that a normal extensional model is not compatible with seismic evidence of nearly-vertical bounding faults. They proposed that the basin developed in a transtensional environment, with a significant component of strike-slip movement along the controlling Burunga-Goondiwindi-Mooki Fault System.

Murray (1985) argued that the Bowen Basin was a ***retroarc foreland basin*** and proposed that the initial subsidence was due to loading of the crust, not by the foreland thrust pile, but by the volcanic and plutonic rocks of the adjacent Camboon Volcanic Arc. A period of Late Carboniferous-Early Permian extensional tectonism that produced half-graben in the Denison Trough and western Taroom Trough, however, has long been recognised (e.g. Paten & others, 1979; Bauer & Dixon, 1981; Cosgrove & Mogg, 1985). Subsequently, Hammond (1987) proposed the application of a ***crustal extension model*** to explain the early development of the Bowen Basin. Using this model, Mallett & others (1988) presented a three-stage history to describe the tectonic development of the Bowen Basin, based largely on the work of Ziolkowski & Taylor (1985) in the Denison Trough. In the Early Permian, the area underwent a ***rift phase***, with thick sediments deposited in the Denison Trough, and abundant volcanics in the Taroom Trough. Bounding faults had a NNW-SSE orientation, following basement grain. The andesitic volcanics in the eastern part of the basin were the product of the Camboon Volcanic Arc, a major feature coincident in location with the Devonian-Carboniferous Connors-Auburn Volcanic Arc (Day & others, 1983). This extensional regime was followed by a period of ***thermal relaxation***, with shallow and marginal marine sedimentation over most of the basin and thick deposits in the Taroom Trough. Compression, with some inversion of half-graben successions, was initiated during the late Early-early Late Permian. During the Late Permian, the basin underwent a ***foreland basin phase***, with widespread marine transgression, followed by coal measure sedimentation. Deposition was concentrated in the Taroom Trough. In the latest Permian-Middle Triassic, the basin was subjected to a period of shortening with reactivation of the bounding faults, partial inversion of the basin and the development of new high-angle reverse faults (Ziolkowski & Taylor, 1985). The Gogango Overfolded Zone on the eastern side of the basin contains westward-directed thrusts and tight folds which are consistently overturned to the west; it has a typical foreland fold-thrust belt geometry (Murray, 1985).

As part of their extensional model for the initial development of the basin, Hammond (1987) and Mallett & others (1988) proposed the existence of a set of northeast-southwest trending transfer faults. These inferred faults divide the basin into domains that are internally consistent with respect to NNW-SSE trending features, but which are significantly different from adjacent domains.

In 1989 the BMR conducted a deep seismic reflection survey in the Bowen Basin to test various tectonic and structural models for the basin. Line BMR89.B01 (see Korsch & others, 1990c for location) was located in a corridor between two of the postulated transfer faults. The data from this line suggest that the Permo-Triassic succession thickens to the east. The seismic line clearly illustrates the deformation of the sedimentary succession, which is controlled by thin-skinned thrusting on a series of listric faults that dip to the east. These faults root in a major detachment that also dips to the east and appears to flatten in the ductile zone in the middle crust (Korsch & others, 1990c). BMR89.B03 was positioned to cross two of Hammond's postulated transfer faults, but there was little evidence on this line to suggest their presence.

As mentioned above, a number of authors (e.g. Harrington & Korsch, 1979, 1985; Korsch & others, 1988, 1990b) have suggested that a significant component of strike-slip movement was involved in the initial development of the Bowen Basin. The results of a deep seismic profile across the southern Bowen Basin (BMR Traverse 14, Wake-Dyster & others, 1987) indicate that the eastern bounding fault of the Taroom Trough is nearly vertical; Korsch & others (1988; in press; in preparation) therefore suggested that the trough did not develop as a result of pure extension in the plane of the section, but rather that the basin-forming mechanism was ***oblique extension.***

In the study area, the Bowen Basin is overlain by the relatively flat-lying sediments of the Surat Basin. Deposition ceased in the Bowen Basin in the Middle Triassic and parts of the basin underwent deformation and uplift. Harrington & Korsch (1985b) related this phase of deformation and the subsequent cessation of deposition to the accretion of the Gympie Terrane(s) to the eastern margin of Australia. The Bowen Basin structures underwent peneplanation prior to deposition of the Surat Basin succession. The structural axis of the Surat Basin is the Mimosa Syncline, which overlies the Taroom Trough. Structures within the Surat Basin succession were generally formed by reactivation of Permo-Triassic structures within the underlying Bowen Basin, which led to minor fault displacements and fault-related folds. The Jurassic-Cretaceous structural style was generally compressive (Elliott, 1989), although there is evidence of strike-slip movement on some faults (Cosgrove & Mogg, 1985). The basin was tilted to the south in the Late Cretaceous and affected by minor faulting in the mid-Tertiary (Elliott, 1989). Veevers (1984) classified the Surat Basin as a distal foreland basin.

In summary, the Bowen Basin was initiated in the latest Carboniferous-Early Permian as a result of back-arc extension associated with subduction along a continental margin volcanic arc (Camboon Volcanic Arc). Following a period of regional sag, the basin was affected by ENE-WSW directed compression during the mid-Permian; this can be interpreted as the onset of foreland basin conditions. From the Late Permian to the late Early Triassic, foreland loading resulted in accelerated subsidence and the reactivation of earlier extension-related structures. This period of shortening culminated in the late Early Triassic or Middle Triassic and deposition ceased. After erosion and peneplanation in the Late Triassic, sedimentation resumed in a gently subsiding intracratonic sag (Surat Basin).

SEQUENCE BOUNDARIES AND SEQUENCES IN THE TAROOM REGION (ATB)

SEISMIC INTERPRETATION METHODOLOGY

The seismic sequence analysis was carried out by identifying discontinuities on the basis of reflection terminations according to the method of Vail (1988). The seismic sections were first examined for places where two reflections converge, and these reflection terminations were marked with arrows. Where a number of such terminations occur along a reflector (or locally, a non-reflecting horizon), the discontinuity surface between truncating reflections below and onlapping and downlapping reflections above was drawn in with a colored pencil. Each reflection was given its own color and a provisional code number; we anticipate that permanent designations will be given to significant reflectors later. Discontinuities which become conformable were traced across the section by reflection correlation. Some reflectors which were not apparent discontinuity surfaces were also selected at this stage on the basis of the strength of their reflections. Correlation was continued onto intersecting lines, and all closed loops were checked by tracing the loop ties for each reflector. If drilling had taken place on or near a seismic line, the formation depths were converted to seismic two-way travel time using the supplied time-velocity table, and tied to the seismic section. Different published lithological well-picks and time-depth tables inevitably gave disparate results for the same well, and emphasise the need for caution with well ties. In future, generating synthetic seismograms for wells may enable well ties to be made with greater confidence. The interpreted seismic line was then digitized using Petroseis^{TM} software and checked for mis-ties. In addition, any discernable stratal patterns and intra-sequence formation patterns were noted.

No attempt has been made at present to identify systems tracts. This is because most of the succession preserved in the region is non-marine, and the marine portion, mostly Permian, is relatively thin. Discriminating between systems tracts in non-marine sediments is not only difficult, but the sequences themselves may be more related to sediment supply and tectonics than to sea-level changes.

REFLECTORS AND SEQUENCE BOUNDARIES

Fourteen reflectors, eight of them sequence boundaries, were chosen as the framework for seismic interpretation in the study area (Fig. 3, Table 1). Eleven of these are within the Bowen Basin succession, one is the major unconformity between the Bowen and Surat Basins, and the remaining two lie within the lower Surat Basin succession. Thirteen of the reflectors (including seven recognised sequence boundaries) were used as mapping horizons.

In the descriptions that follow, examples of reflectors are generally not illustrated with diagrams, but reference is made to the sesimic sections in which the reflection can be inspected.

Permian

The basal Permian consists of a thick

volcanic sequence, known as the Camboon Andesite (Fig. 3), reached by the UOD Cockatoo Creek 1 well and exposed along the eastern side of the basin. The contact between the volcanic rocks and the underlying basement is not apparent in the seismic sections. A prominent reflector with onlaps at about 2200-2700 ms in line S84-CT-03 is interpreted as the near-strike intersection of a fault, which is seen to be a thrust in orthogonal lines S84-CT-02 (Fig. 4) and S84-CT-08.

The volcanics are overlain by Early Permian marine rocks, the base of which is a regional sequence boundary provisionally designated B6. This surface is usually marked by a high acoustic impedance contrast, and typically exhibits a strong peak flanked by strong troughs. A good example occurs in line C83-GL-02 at SP 420, 3000 ms. The only ties with wells in the Taroom region are poor ones to the base of the marine interval in UOD Cockatoo Creek 1 (Fig. 5) and MPA Glenhaughton 1.

Within the marine succession three reflectors have been selected. The lowest one (B39) is recognized only in the northwest corner of the region under consideration, as a sequence boundary at the base of the Freitag Formation. In that area, the Freitag base in Glenhaughton 1 corresponds to a moderately strong reflector only short distance (about 50 ms) above the base of the marine sediments, e.g. in line T82-RC-03 at SP 130, 1300 ms. This level was identified from well logs as an unconformity by Cundill & Meyers (1964). It is interpreted as corresponding to the major unconformity in the eastern Taroom Trough where the whole of the Fauna III zone (Dickins, 1964) is missing, but there it merges seismically with the underlying sequence boundary because the Buffel Formation is too thin to be resolved.

In the rest of the region there is a stratigraphically higher, usually strong but variable amplitude reflector (B26), exemplified by the strong trough flanked by strong peaks in line S84-BM-06 at SP1950, 3400 ms. It is tied reasonably well to Cockatoo Creek 1, at or above the base of the Flat Top Formation. Though it shows no explicit evidence of being a sequence boundary, and is not recognized in the northwest corner of the region, recent palaeontological work (Parfrey, 1988) suggests that it is possibly equivalent to the base of the Peawaddy Formation (B27) in the Denison Trough to the west. The latter level has been interpreted to be of tectono-sedimentary significance by Dickins (1983), in that it records a marine transgression, which is unconformable in places and marked by the immediate introduction of volcanic detritus.

The next reflector (B64) ties in poorly at or above the base of the Gyranda Formation in Cockatoo Creek 1, and is the strong reflection in line C83-GL-02 at SP 480, 2740 ms. The well tie is poor because the reflector, like many of the others, deteriorates in quality towards the structural high. Throughout this region the horizon usually displays no sequence boundary characteristics, but in section S84-BM-06 at SP 1815, 1845 and 1890 it truncates beds below it, and in section C83-GL-02 at SP 120, 185, 250 and 380 there are strata lapping onto it. It may therefore be a subtle expression of such a boundary, especially if it could be correlated across a gap in the seismic coverage to the base of the Black Alley Shale in the northwest corner. There, B64 may correspond to the very weak reflector (B63) defined by the truncation of beds below it in line T82-RC-03 at SP 226, 1300 ms, and matching with the base of the Black Alley Shale in Glenhaughton 1. Our field studies have revealed that the contact between the Peawaddy Formation and the overlying Black Alley Shale in a section

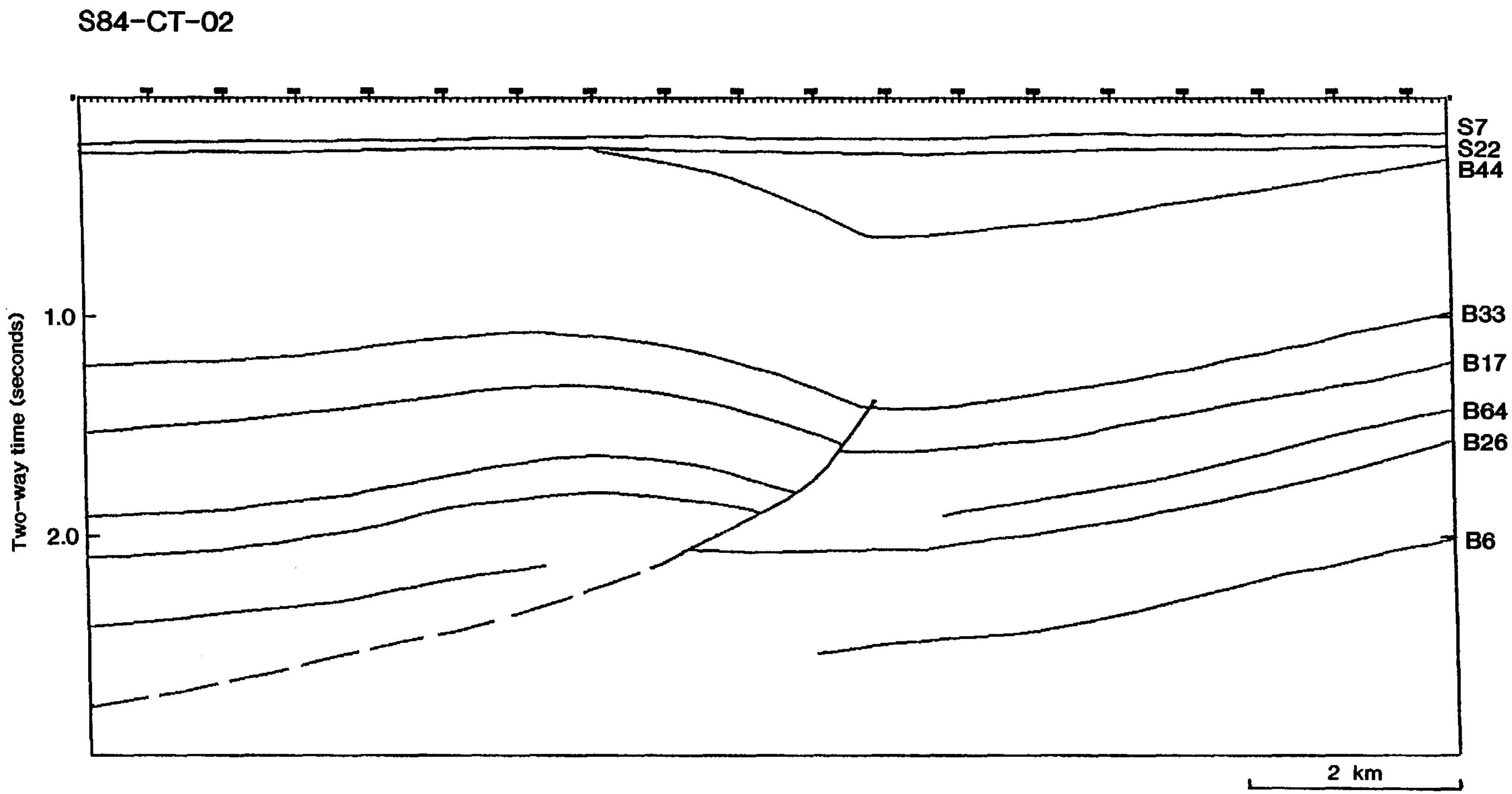


Fig. 4. Interpreted geology along seismic line S84-CT-02.

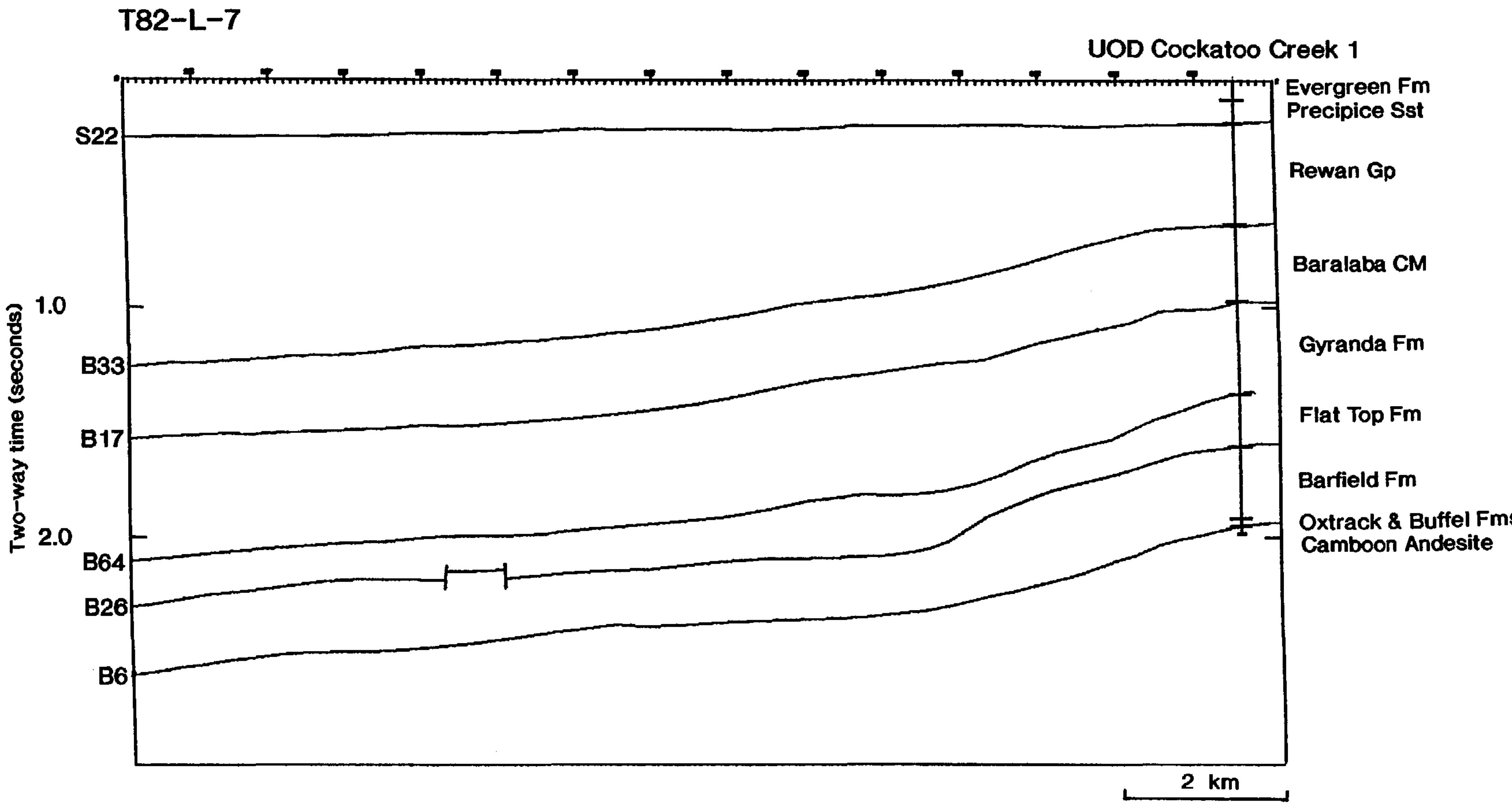


Fig. 5. Interpreted geology along seismic line T82-L-7 showing tie with Cockatoo Creek 1.

near Carnarvon Gorge is a sequence boundary truncating sandstone and mudstone beds; the suggestion of a hiatus between the Black Alley Shale and Peawaddy Formation in figure 4 of Dickins (1983) fits in with our observation. There is also evidence of truncation associated with this horizon on some seismic lines in the Denison Trough to the west.

The base of the Baralaba Coal Measures is usually expressed as a well-marked reflector (B17) at the base of a zone of strong reflections, as in line C83-GL-02 at SP 480, 2530 ms. The tie to the COE Tiggrigie Creek 1 well is good, while that to the Cockatoo Creek 1 well, and to the base of the equivalent Bandanna Formation in Glenhaughton 1, is fair. As with the two preceding reflector picks (B64 and B26), this horizon is not readily apparent as a sequence boundary in the Taroom region. It shows some truncation of underlying beds in only two (possibly four) seismic sections, so it is doubtful that it is a sequence boundary, but it may be a parasequence boundary. It strikingly truncates beds in one seismic line in the Denison Trough, although this could record local tectonic movement.

The top of the coal measures and base of the Rewan Group is one of the most obvious of the sequence boundaries, confirming the numerous references in the literature to a regional scour surface at this level. Erosional relief on it is sometimes visible in the Taroom region, but the greatest incision, exceeding 30 m, is displayed in lines to the west and northwest of the study area. Underlying strata are truncated in many sections, and locally there are onlaps (Brakel & others, 1992, fig. 3) and downlaps onto it. The downlaps were probably formed at the toes of lacustrine delta foresets. The horizon is generally a strong reflector (B33) at the top of a zone of strong reflections caused by coal seams, as, for example, in line C83-GL-03 at SP 480, 2300 ms. The well ties to the Rewan base are fair in Cockatoo Creek 1 and reasonably good in Glenhaughton 1.

Triassic

Of the five reflectors picked within the Triassic succession, all except the lowest one (B44) have been identified for certain as sequence boundaries. B44 is truncated by the sequence boundary above it in line C83-GL-02 (Fig. 6), and is therefore locally absent. In line S84-BM-06 at SP 1950, 2000 ms, the B44 reflection is the strong trough flanked by strong peaks, but on many other lines it is poorly defined. Although its nature is obscure, it can be seen probably truncating strata below it in line T83-WA-06. Its position in the seismic sections locates it in the upper Rewan Group.

The reflector (B48) that truncates B44 (as well as many other beds) is only intermittently well developed. It is a strong reflector in lines S84-BM-06 (e.g. at SP 1715, 1700 ms) and C83-GL-02, and ties to the base of the Clematis Group in the Tiggrigie Creek 1 well on line C83-T-4, where it separates two distinctly different packages of reflectors. The Clematis base has been described previously as locally disconformable (Dickins & Malone, 1973) or erosional (Elliott & Brown, 1988).

A reflector within the Clematis Group (B20) shows high impedance contrast in places, such as in line S84-BM-06 at SP 1630, 1200 ms, but is not evident as a sequence boundary from the seismic. However, it ties approximately with the base of the Showgrounds Sandstone in Tiggrigie Creek 1, a unit that elsewhere is known to have a hiatus below it (Elliott & Brown, 1988), implying that it is an erosion surface. The next reflector pick (B46 - SP

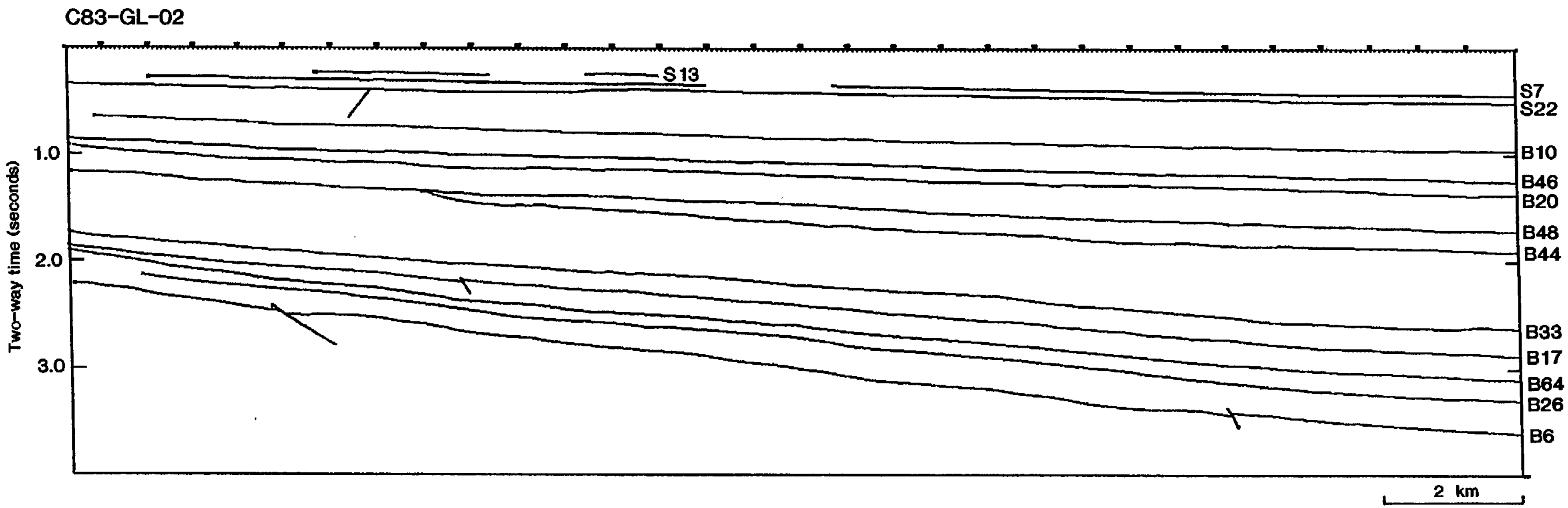


Fig. 6. Interpreted geology along seismic line C83-GL-02.

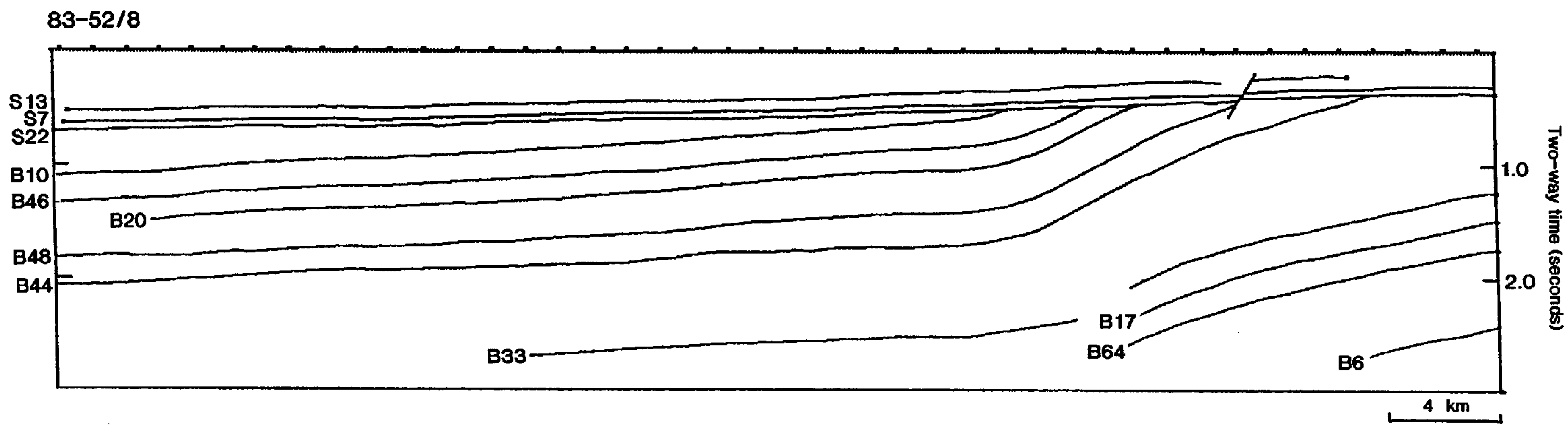


Fig. 7. Interpreted geology along seismic line 83-52/8.

1820, 1299 ms in line S84-BM-06) truncates underlying beds in some lines, and in C82-T-54 it cuts off the B20 surface. Usually, however, it does not show this trait, and on the poorer quality seismic lines it can be difficult to identify. In the Glenhaughton 1 area it is the only non-Permian sequence boundary that can be recognized. It correlates with the base of the Moolayember Formation in Tiggrigie Creek 1. A better-developed truncation surface (B10) is present within the Moolayember Formation, and is typified by the reflector at SP 1820, 240 ms in line S84-BM-06.

Jurassic

The base of the Surat Basin succession (S22) is the strongest unconformity in the region (e.g. SP 4740, 240 ms in line S84-CT-03). It represents the peneplanation surface formed during the Late Triassic, following a major compressional episode. Erosional trimming of uptilted beds is conspicuous near the eastern margin of the Bowen Basin (e.g. line 83-52/8, Figs 7 and 8). In the axial portion of the Taroom Trough the angular discordance is not as great, and in places the reflectors are parallel.

Two reflectors have been picked in the overlying sediments, corresponding to the Precipice - Evergreen boundary (S7) and the oolitic Westgrove Ironstone Member of the Evergreen Formation (S13) in the GSQ DRD 6 bore. S7 is the strong reflector in line S84-CT-03 at SP 4740, 180 ms, but can be difficult to pick in some other lines. S13 is the strong reflector in the same line at SP 4950, 140 ms. No seismic evidence has so far been found that either is a sequence boundary, however Elliott & Brown (1988) report a reflector at the S13 level as a "basin-wide sequence boundary". The Westgrove Ironstone Member records widespread chemical sedimentation, denoting a deficiency of clastic input, at the time of a marine incursion. Such "sediment starvation" is indicative of a maximum flooding surface.

SEQUENCE CHARACTERISTICS

Permian

Internally, the basal Permian volcanics usually display poor or broad reflections, because the higher seismic frequencies are filtered out by the overlying sedimentary pile so that only the lower frequency, long wavelength energy remains. Nevertheless, in several sections, such as C83-GL-02, some strong reflections are present, implying lithological contrasts between beds, perhaps due to differing lava compositions or interbedded clastics. Bifurcations and terminations of reflectors are evident in places (e.g. SP 280-320, line T83-FV-06); a lenticular body at SP 275-345 in line S84-BM-01 may be the cross-section of a lava flow, and there is onlap of a reflector at SP 220-310 in line T82-RC-05.

The marine Permian (B6-B17) is generally characterized by less prominent reflections than in the adjacent units, although locally some strong reflections are present. The lower part of the marine interval (B6-B26) tends to have weak to disorganized reflectors, the middle portion (B26-B64, approximately equivalent to the Flat Top Formation) has better developed reflectors, while the upper portion (B64-B17, approximately the Gyranda Formation) ranges between these in style. [Note that the Gyranda Formation is often interpreted as non-marine, based on the occurrence of a few thin coal seams, but this view is not universal. In UOD Burunga 1 the formation contains some marine shells. It is likely that the unit represents an interfingering of

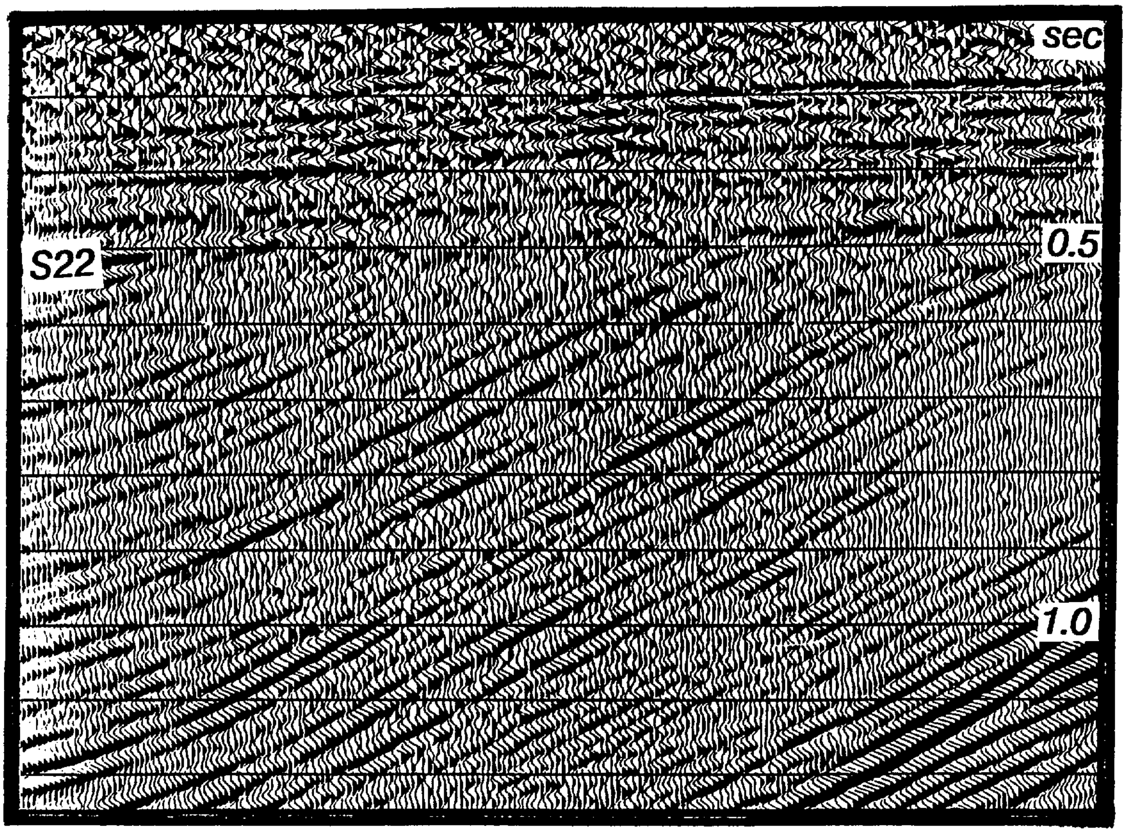


Fig. 8. Unconformity between the Bowen and Surat basins (S22) in part of seismic section 83-52/8 between stations 760 and 870. Vertical scale in two-way travel time.

marine and non-marine facies.] In the area around Glenhaughton 1, the sub-Freitag sequence boundary (B39) lies only one reflector above the top of the volcanics, and the rest of the marine interval is so poorly expressed seismically that even the sequence boundaries between B39 and B17 cannot be recognized without reference to the Glenhaughton 1 well. The only stratal patterns of note within the marine sequences are uncommon bifurcations and terminations of beds, apparent downlaps in the Black Alley Shale in section T83-FV-05, and possible foresets around SP 4540 and 4740 in section S84-CT-03.

The Late Permian coal measures (B17-B33) typically display strong reflectors at the interfaces between coal seams and clastic interbeds. Bifurcations and terminations of strata due to seam splitting and pinch-outs are ubiquitous, and channels are fairly common. Some prograding foresets, presumably deltaic, are visible (SP 134-140, line 80-H70, and SP 100-103, line 80-H74).

Triassic

The non-marine succession of the Rewan Group, Clematis Group, and Moolayember Formation is generally at least twice as thick as the Permian succession above the Camboon Andesite, and comprises five recognizable genetic sequences. Strata are characterized by great lateral variability, ranging from strong to poor, and from continuous to lenticular reflectors, even within the one seismic section. Line C83-GL-02 is a good example of the variability that is possible. This is due to lateral lithological changes within a largely fluvial assemblage of stacked channel and overbank deposits. Some of the reflectors in the Triassic succession, including some sequence boundaries, may represent paleosol horizons; Jensen (1975) noted the presence of paleosols throughout the Rewan and Clematis Groups.

In the Rewan Group (B33-B48) there is a tendancy for the lower part of the unit to have weaker and less continuous reflectors than the upper part, indicating the difference between the Sagittarius Sandstone and the overlying redbeds of the Arcadia Formation. At the base of the Rewan Group, strata commonly show onlap or downlap onto the underlying sequence boundary. Higher up, bifurcating strata, prograding foresets (e.g. line T82-L-101, SP 135, 225, 270) and large channels (e.g. same line, SP 200) can be identified in places. These features are to be expected in a fluvial facies with sporadic lakes. Notable in section S84-BM-04 (SP 2600-2725) is the occurrence of a stacked series of 13 clinoform sets, above and below reflector B44, recognizable as such over a distance of about 3 km, although they can be correlated farther. Their thicknesses vary from 160 to 310 m (average 215 m). They are not visible on any other section, and their formation was probably a function of local conditions. A tentative interpretation is that they are lacustrine delta parasequences, each formed when subsidence caused the previous delta lobe to sink below the lake surface, creating accommodation space for the next delta lobe to build out. S84-CT-03, a NNE-trending section, exhibits a remarkable series of convex-upwards patterns (SP 5050-4800), which we interpret as alluvial fans extending over a distance of 9 km, that were supplied from the same point sources until they accumulated sedimentary piles to compacted thicknesses of up to 2.2 km. Similar patterns occur in approximately N-S sections S84-CT-05, C83-GL-03 and T82-RC-01.

Two sequences have been recognized in the Clematis Group correlative. In many lines, such as S84-BM-06, the lower B48-B20 sequence is similar to the lower Rewan Group in seismic expression, in that beds tend to be weakly reflecting and lenticular, whereas the upper B20-B46 sequence (the Showgrounds Sandstone equivalent) typically has stronger and more continuous reflectors than the adjacent intervals. In other lines such as C83-GL-02 and C83-T-4, however, the reverse situation exists, again illustrating the spatial variability of fluvial deposits. Some westerly-prograding foresets downlap onto the Clematis base (B48) east of SP 1770 in section S84-BM-06.

The Moolayember Formation correlative, with its two identified sequences, is generally similar in seismic style to the rest of the Triassic succession, but there is usually a greater abundance of medium to strong reflectors, and because the unit lies at shallower depths where most higher acoustic frequencies have not been attenuated, a finer resolution of strata has often been achieved. On many lines, such as S84-BM-01, the lower sequence (B46-B10) has weaker and less organized reflectors than the upper one (B10-S22), but in other sections there is no appreciable difference in seismic response between the two genetic sequences. Bifurcation patterns are common in S84-BM-01, S84-BM-06, T83-FV-04, and T83-FV-06.

Jurassic

Poor quality seismic recording is common for the Jurassic interval over most of the region, due in part to its very shallow depth. Where better quality was obtained, moderately strong reflectors are seen, and usually they are more numerous in the meandering fluvial to lacustrine and marine lower Evergreen Formation (S7-S13) than in the braided fluvial Precipice Sandstone (S22-S7), as in line S84-BM-01. The relative abundance of reflectors is interpreted as being indicative of the degree of sandstone-shale interbedding. Only rarely are structures other than planar bedding discerned; delta foresets occur at SP 4940-4970 in line S84-CT-03 in the lower Evergreen, and possible channels may be present in the Precipice Sandstone of line S84-BM-01. No downlaps onto the S13 maximum flooding surface have been found to date.

TABLE 1. EVIDENCE FOR SEQUENCE BOUNDARIES IN THE TAROOM REGION

This compilation gives examples of evidence and possible evidence for sequence boundaries (SBs) in the Taroom region. Some of the observations are tentative, especially in poor quality lines such as the 1962 series (AA, BB62, BD, etc.), 80-H-79, and 80-H-80.

B6 - base of Permian marine sediments

* Well ties (Cockatoo Ck 1, Glenhaughton 1) to the Camboon / Back Creek boundary
* Truncates beds in lines T82-L-105 (SP185), T83-FV-04 (SP200), T83-FV-05 (SP195, 280), T83-FV-06 (SP133, 288, 330), AA62B (SP55-61), BB78 (SP78-80), BD
* Possible downlaps in lines AA62B (SP55-63), BD.

B39 - base of Freitag Formation

* Truncates beds in lines T83-FV-04 (SP244-260), T83-FV-06 (SP270, 285, 325)
* Well tie (Glenhaughton 1) to the Freitag Formation base, which is known to be an unconformity from drilling in the Denison Trough (Cundill & Meyers, 1964), outcrops, and palynology.

B26 - base of Flat Top Formation

* Truncates beds in lines T82-L-106 (SP225, 255), AA62B (SP59), BD, and possibly in lines S84-CT-05 and T82-L-6 (SP270-310)
* Downlaps in lines AA, BB62 (SP193), BD
* Well tie to the basal Flat Top Formation, which Parfrey (1988) correlates with the basal Peawaddy Formation. The latter is marked by the introduction of volcanic detritus, implying tectonism, and the lensing out/truncation of the Catherine Sandstone. Dickins (1983) interpreted the Peawaddy base as recording a major tectono-sedimentary change, also involving marine transgression and local unconformity.

B63 - base of Black Alley Shale

* Truncates beds in T82-RC-03, T82-RC-05 (SP140, 190), T83-FV-06 (SP253), and possibly in T82-RC-04 (SP255)
* Possible onlap in line T83-FV-04 (SP290)
* Well tie (Glenhaughton 1) to the Black Alley base. This is a SB in outcrop near Carnarvon Gorge, where sandstone and mudstone beds are truncated, and it is also a palaeontological hiatus (Dickins, 1983).

B64 - base of Gyranda Formation

* Truncates beds in line S84-BM-06 (SP1815, 1845, 1890), and possibly in AA62B (SP54-62), BD
* Possible channel in line T82-L-2 (SP265)
* Downlaps in line AA, and possibly BD (SP91-92)
* Onlaps in line C83-GL-02 (SP120, 185, 250, 380)
* May correlate with B63, a SB.

B17 - base of Baralaba/Bandanna Coal Measures

* Truncates beds in lines T83-FV-06, AA62B (SP61), possibly in lines AA, T82-L-5 (SP325, 370)
* Onlaps in line AA
* Downlaps in lines AA, and possibly BD (SP97-98)

B33 - base of Rewan Group

* Truncates strata in many lines (e.g. S84-CT-03, C83-GL-03, C83-GL-06, T82-L-102, 80-H-76, T83-WA-05)
* Erosional relief visible in some lines (over 30 m in 81-H-50 [SP370, Arcadia area] and 70-M1 [SP250, Warrinilla area])

TABLE 1: Continued

* Channels in line T83-FV-01
* Onlaps in lines AA, 80-H-79, AA62B (SP38, 59)
* Downlaps in lines AA, T82-RC-04 (SP150-250), S84-BM-01, S84-BM-04, C83-GL-02
* Known to be a regional scour surface from outcrop studies (Mollan & others, 1969; Jensen, 1975; Chiu Chong, 1969).

B44 - intra-Rewan Group

* Truncates beds in line T83-WA-05, and possibly in lines C81-T-29, AA, T83-FV-01
* Downlaps in line AA

B48 - base of Clematis Group

* Truncates B44 in line C83-GL-02, C81-T-38, C83-T-1, C82-T-52
* Truncates beds in lines T82-L-105, BB62, C83-T-4, C82-T-54, C81-T-29, possibly in line 80-H-79
* Possible erosional low in line T82-L-106 (SP175)
* Possible channel in line S84-BM-01 (SP155-240)
* Possible onlaps in line 80-H-79
* Downlaps in line AA.

B20 - base of Showgrounds Sandstone

* Possible truncation in line S84-BM-01 (SP180)
* Probable erosional relief, truncation and onlap in line S84-BM-04 (SP2630)
* Downlaps (prograding foresets?) in line 80-H-79 (SP112)
* Probable well tie to Showgrounds Sandstone base in Tiggrigie Creek 1, which elsewhere has a hiatus below it (Elliott & Brown, 1988).

B46 - base of Moolayember Formation

* Truncates B20 in line C82-T-54
* Truncates beds in lines T82-L-105 (SP110-140), T82-L-6 (SP300), T83-FV-05 (SP296, 155), T83-FV-06 (SP160, 185)
* Possible channel in line T83-FV-04 (SP207)
* Onlap in line T83-FV-06 (SP130).

B10 - intra-Moolayember Formation

* Truncates beds in several lines, e.g. T82-L-6, T82-L-105 (SP360), 80-H-74, 80-H-79, S84-BM-01, S84-BM-04, S84-BM-06, and possibly C83-T-1, C83-T-10.

S22 - base of Precipice Sandstone

* Major angular unconformity at the base of the Surat Basin (e.g. lines S84-CT-03, T82-L-7, 83-52/8)
* Well ties (Cockatoo Creek 1, Tiggrigie Creek 1) to the Precipice Sandstone base.

S7 - base of Evergreen Formation

* No seismic evidence for being a SB.

S13 - Westgrove Ironstone Member

* No seismic evidence for being a SB
* Correlation with Westgrove Ironstone Member in DRD 6 bore. The widespread chemical sedimentation as recorded by the oolite indicates a dearth of clastic input - such a "starvation surface" is a maximum flooding surface.
* Elliott & Brown (1988) report a reflector at "top of Boxvale Sandstone" (which given the resolution of the seismic is probably the same as what we interpret as S13) as a "basin-wide sequence boundary".

GEOMETRY OF STRATIGRAPHIC SEQUENCES AND STRATIGRAPHIC UNITS (ATW)

DATABASE AND DERIVATION OF DATA

The database on thicknesses of stratigraphic sequences and/or lithostratigraphic units in the Bowen and Surat Basins in the study area was derived from the interpretation of a network of chiefly industry-acquired seismic lines in the Taroom region. The methodology used in the interpretation of the seismic sections and the derivation of the mapped reflectors is described in the Introduction, and in the section on Sequence Boundaries and Sequences in the Taroom region (see above).

The isopach maps (displayed in two-way travel time) are based on the selection of thirteen reflectors in the Taroom Trough, at least seven of which show indubitable evidence of being sequence boundaries. The reflectors on the seismic lines were digitised and the digital data entered and processed by Petroseis^{TM} System software. The Petroseis^{TM} software generates contours of equal seismic two-way travel time through the unit which are not directly equivalent to true isopachs. However, the two-way time isopachs, or time interval contours, can be used as a rough guide to changes in sequence or formation thickness. The two-way time isopachs were converted to approximate thicknesses in metres using rms velocities and two-way time intercepts on the seismic record section. Isopach maps were produced for all the intervals between successive mapped reflectors (formation and/or sequence boundaries), and combinations of these units in the three major successions (Back Creek and Blackwater Groups; 'Mimosa Supergroup'; and the Surat Basin) for analysis and confirmation of interpretation. [The term 'Mimosa Supergroup' is used here collectively for the Rewan Group, Clematis Group and Moolayember Formation. It is used informally in this report but may be properly defined at a later stage.] It should be stressed that the formation identifications shown on the isopach maps are preliminary, mainly because of sparse well control. More definitive identifications will be possible as the interpretation proceeds into areas where there are a greater number of petroleum exploration wells, and hence more precise control on sequence boundary identification.

Previous data

There are numerous references that include data on the distribution and thickness of formations in the Bowen and Surat Basins. However, probably the majority of these references discuss only restricted parts of the basins or treat only one or two units in a small area. Only the references to regional surveys are included in this chapter of the report and the reader is referred to more comprehensive bibliographies (e.g. Dickins & Malone, 1973; Exon, 1976; Day & others, 1983) of the basins for detailed information on local areas.

ILLUSTRATIONS OF ISOPACH GENERATION

Two examples of isopachs generated by Petroseis^{TM} software are shown in Figures 9 and 10. Figure 9 is an isopach generated for the Late Permian coal measures (Bandanna Formation and equivalents; interval B33-B17), and Figure 10 shows the isopachs generated for the Late Permian-Triassic Rewan Group, Clematis Group and Moolayember Formation ('Mimosa Supergroup'; Interval S22-B33). A brief description of each of these intervals will be given to illustrate the detail that can be generated from the contouring package, and the interpretation that can be obtained from the maps.

It should be noted that only a few representative maps discussed here are illustrated by the figures, but all are available at 1:250 000 scale from the BMR Sales Centre, and are listed in Appendix 1.

Late Permian coal measures (Bandanna Formation and equivalents; interval B33-B17)

A central area of relatively uniform sediment thickness (the equivalent of 350-400 ms, that is, approximately 1260 m of coal measures based on calculations using rms velocities on Line T82-L-101 at about SP 500) interrupts the gradual eastward thickening of the coal measures with an equivalent of ~640 ms of sediments situated at the eastern margin of the Bowen Basin in what appears to be a depocentre towards the eastern edge of the Taroom Trough. In this particular case the shape of the depocentre is an extrapolation produced by the contouring program; neighbouring lines are very widely spaced and thus exert little influence on the shape of the isopachs. In addition, the interpretation is based on some poor quality line data and must be treated with caution.

The coal measures thin gradually westward and at the western extremity a broad band of thin sediments that show relatively little change in thickness coincides approximately with the flanks, and in the region towards the crestal area of the Comet Ridge. However there are very few seismic sections in this area and therefore little control on isopach spacing.

The thickness of coal measures apparently still reflects the shape of the basement floor but the isopach gradients show that the influence is more subdued compared to deeper horizons. The meridional trend of the depocentre, ignoring the doubtful thickening in the northeast, is parallel to and roughly coincident with the trend of depocentres in deeper units and hence also with the deepest part of the Taroom Trough. A regional thinning of the coal measures along their eastern mapped extent suggests the presence of a depositional edge in this direction and provenance areas, with possibly exposed basement, in this general region. The presence of conglomerate interpreted as local alluvial fans (Fielding & others, 1990) along the eastern basin margin supports this conclusion.

An isometric diagram, showing the base of the coal measures, is illustrated in Figure 11.

Late Permian-Triassic 'Mimosa Supergroup' (Rewan Group, Clematis Group and Moolayember Formation) (S22-B33)

A summary of the main attributes of this succession is given under the description of regional isopach trends and only the detailed features of the 'Mimosa Supergroup' will be given here (Fig. 10).

The north-northwest trending depocentre lies to the east of the Mimosa Synclinal axis and contains in excess of 2600 ms equivalent of the sedimentary section (at the north end of Line T83-WA-09, and on Line T83-WA-06) in the central northern part of the Taroom Sheet area. The sedimentary wedge is the preserved remnant of the Late Permian to Middle Triassic, and possibly as

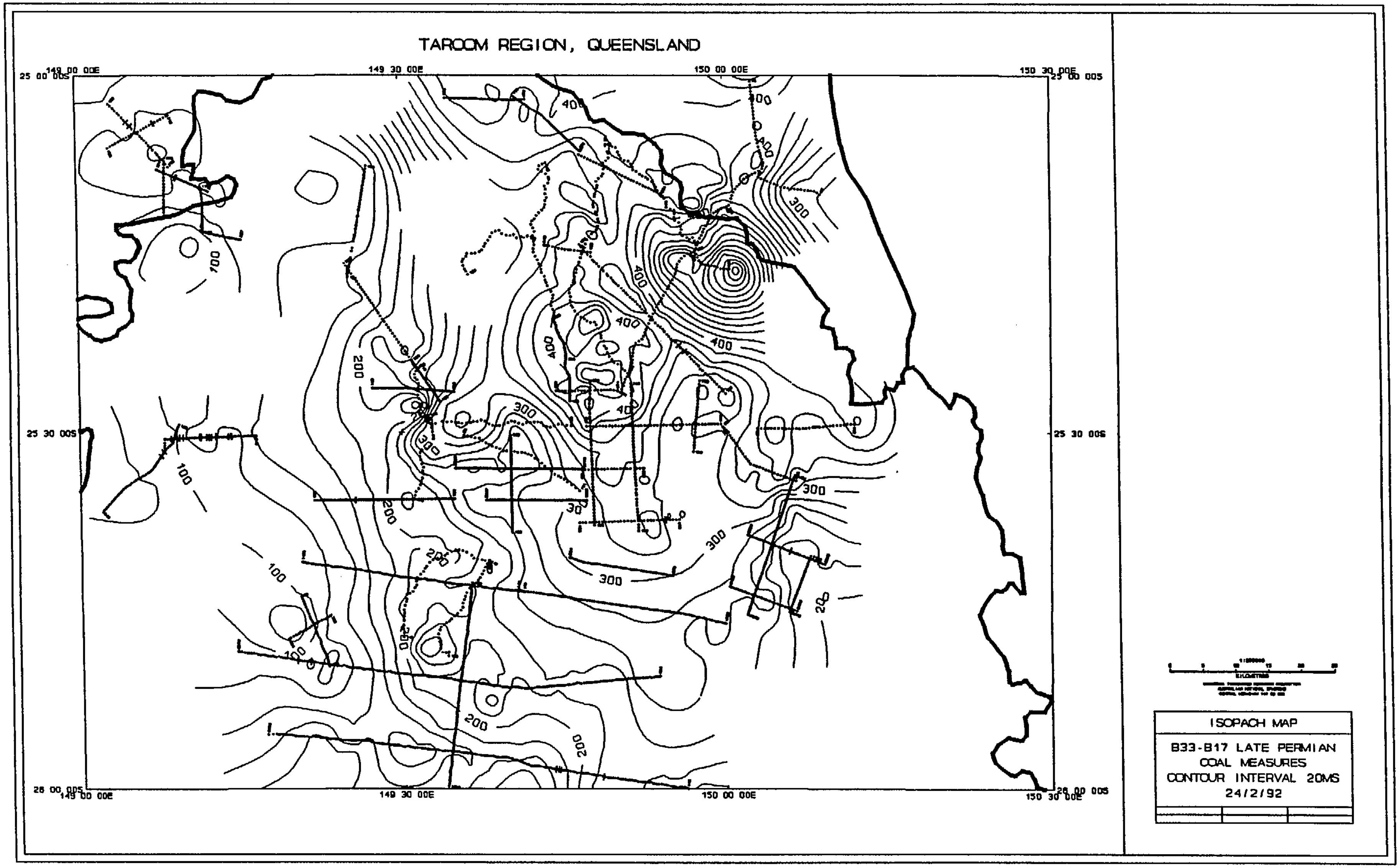


Fig. 9. Isopach map in two-way time of the succession between reflectors B17 and B33 (approximately equivalent to the Late Permian coal measures).

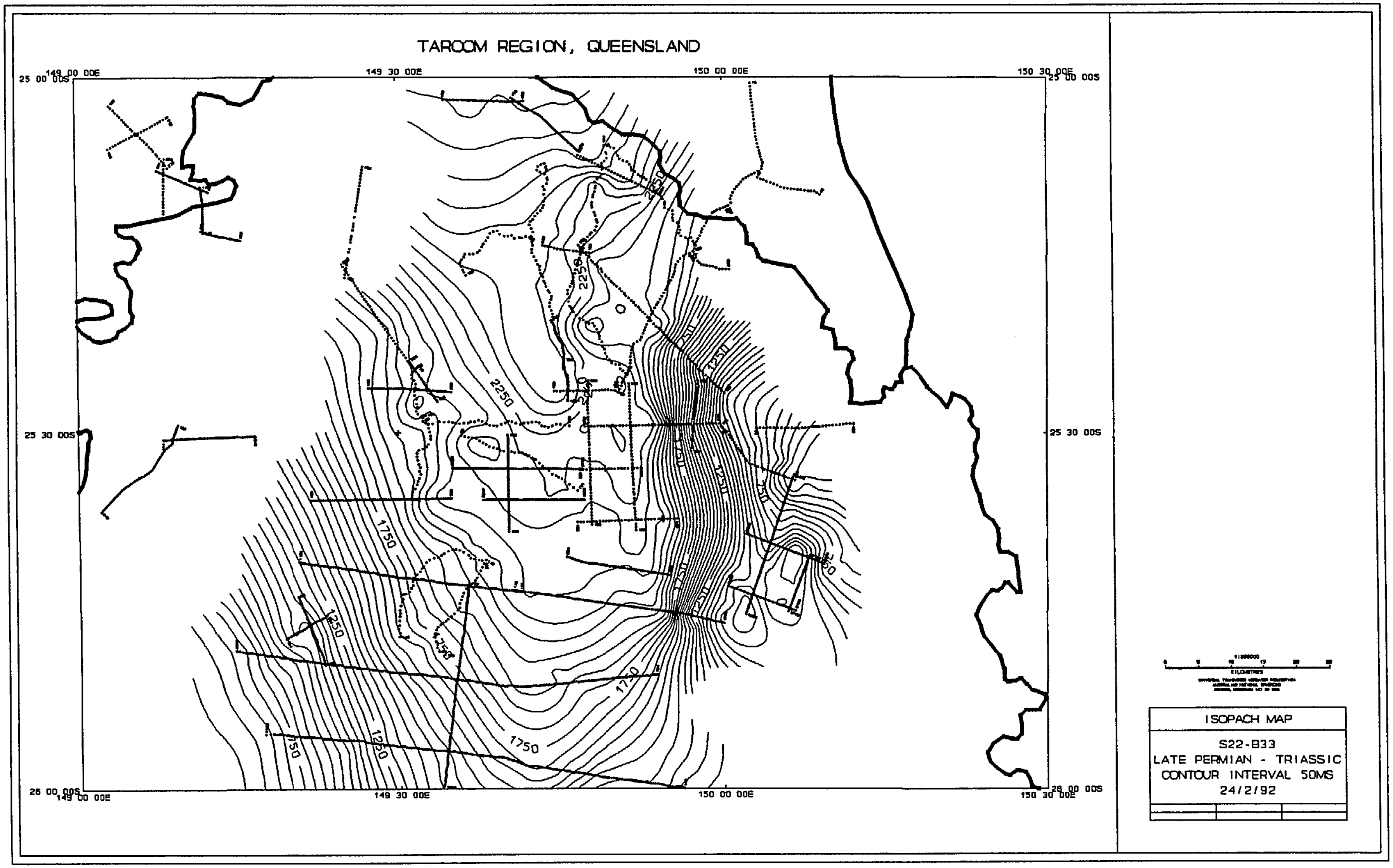


Fig. 10. Isopach map in two-way time of the succession between reflectors B33 and S22 (approximately equivalent to Rewan Group, Clematis Group and Moolayember Formation)

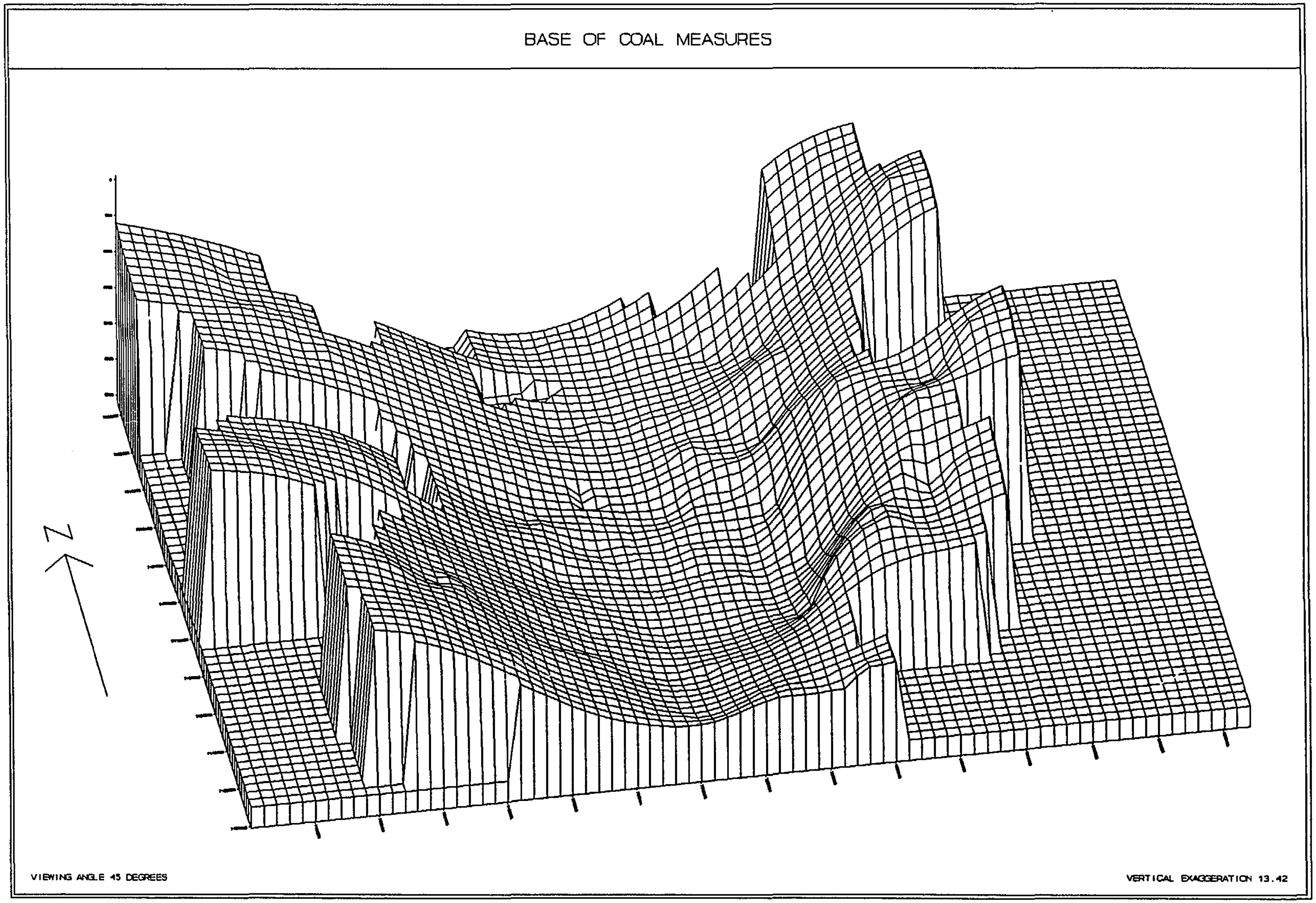


Fig. 11. Isometric diagram of the B17 reflector (approximate base of the Late Permian coal measures).

young as early ?Late Triassic (Evans, 1964; Burger, 1992), succession beneath the Jurassic sediments of the Surat Basin. The thickness of preserved sediments is in excess of 7000 metres based on calculations using rms velocities from line T83-WA-06. This figure is in broad agreement with the aggregate of the maximum thicknesses estimated by Dickins & Malone (1973), but both sets of figures should be regarded as very approximate.

The thickest sediments occur in a relatively narrow north to northwesterly (north in the southern part of the mapped area and northwest in the northern part) trending zone with the succession increasing in thickness gradually and consistently to the northwest. The axis of the greatest thickness of sediments along the north-west trending depocentre is approximately parallel with the axis of the Mimosa Syncline and even more approximately with the axis of the Taroom Trough. It is displaced reasonably consistently up to about 10 km to the east-northeast of the plotted approximate position of the synclinal axis on the geological map and slightly less when compared with the position of the axis of the syncline determined from seismic data (see structure contour on S22 below, Fig. 16). This phenomenon could be explained by assuming that the Triassic sediments were asymmetrically folded before erosion. Alternatively the thickness of Triassic sediments could have originally increased markedly to the east so that the depocentre is apparently east of the fold axis subsequent to folding.

The Triassic succession decreases in thickness relatively more rapidly to the east compared to the western flank of the depocentre axis. This is caused by the Late Triassic uplift of the Bowen Basin sediments along the eastern side of the Taroom Trough with strong uplift apparent on the western flank of the Auburn Arch and near the Burunga Fault. Thinning of the sediments here was partly caused by structural growth during sedimentation and partly by subaerial erosion after the Late Triassic uplift. It is apparent from the cross setions displayed on several seismic lines across the basins (for example on the fence diagram, Fig. 12) that the width of the tilted Triassic sediments affected by this erosion was a minimum of 25 km.

Two small closures on the south-east side of the mapped area are structurally controlled; the closures are produced by the preservation of sediments in truncated folds beneath the Surat Basin (see section on Structural Configuration and Tectonic Development below). One of these is shown on Line S84-CT-02 (Fig. 4).

There is insufficient control on the isopachs to the west to indicate any strong regional trend. The western side of the mapped area lies in the region of the Comet Ridge and here the sediments are relatively thin and flat lying. The sedimentary section thins gradually westwards towards the Comet Ridge and is well illustrated on Line C83-GL-02 (Fig. 6).

DESCRIPTION OF REGIONAL ISOPACH TRENDS

The following description is a summary of the main attributes of the distribution and thickness trends shown by the three major groups of sedimentary successions in the Bowen and Surat Basins, the Blackwater and Back Creek Groups (essentially the Permian succession), the 'Mimosa Supergroup' and the Surat Basin sediments.

Although only the major groups are discussed and illustrated here (Figs 9, 10 and 16) it is worth noting that within the three major groups described (Back Creek and Blackwater Groups; 'Mimosa

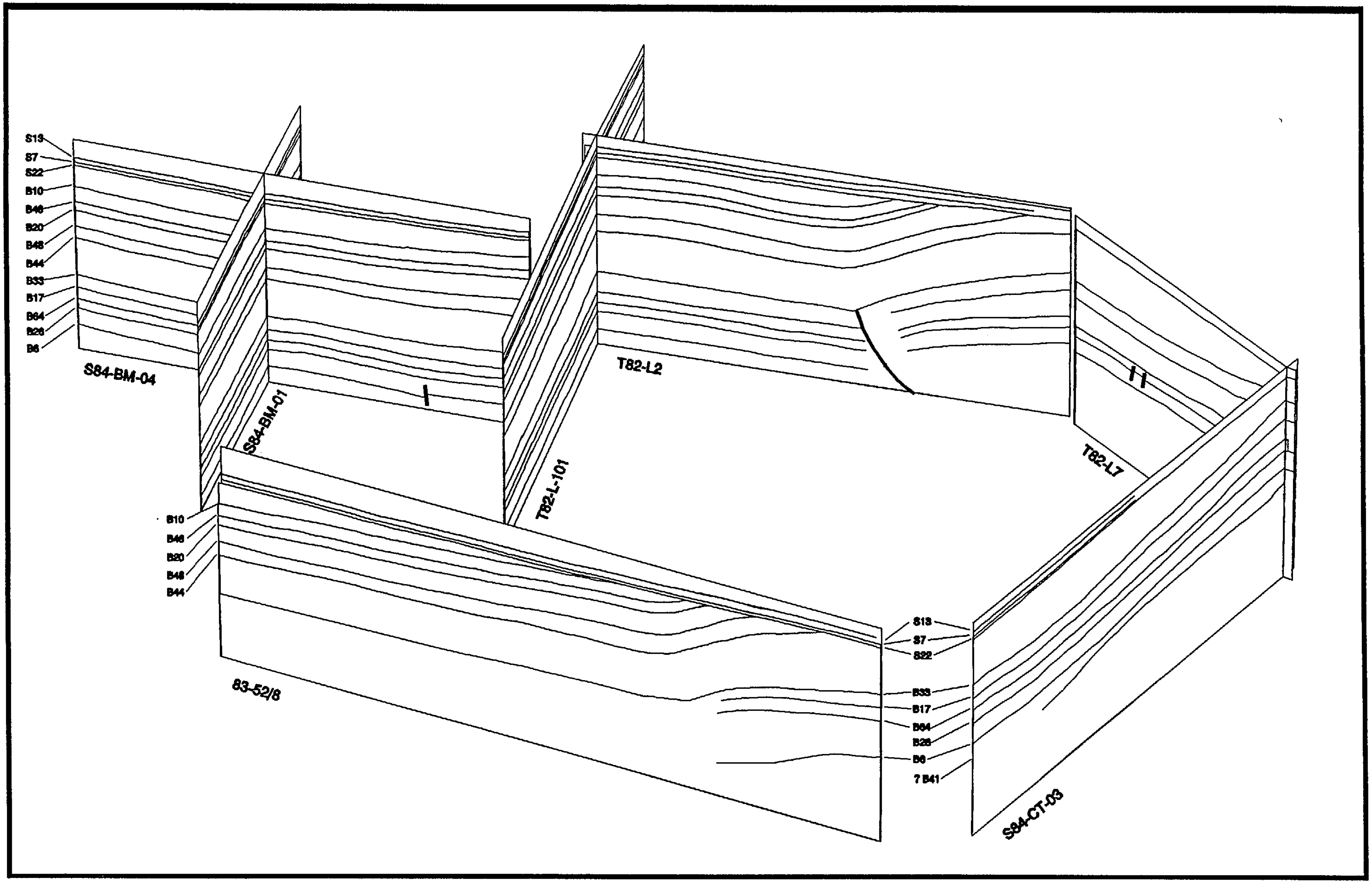


Fig. 12. Fence diagram of part of the Taroom region showing faulted monocline at eastern margin of Taroom Trough and unconformity beneath the Surat Basin succession. Azimuth 165°, viewing angle 35°.

Supergroup'; and Surat Basin succession) there are changes in isopach gradients, trends, and depocentres from one mapped unit to another that probably reflect the presence of bounding unconformity surfaces. Hence units above and below sequence boundaries are more likely to show disparate isopachs compared with the boundaries of conformable stratigraphic units.

Back Creek and Blackwater Groups (B33-B6)

With a few exceptions the isopachs for the Back Creek and Blackwater Groups generally show the following features:

1. A regional easterly increase in thickness of constituent units.

2. A roughly meridional trend of the isopachs, with some showing north-northwesterly trends.

3. Depocentres are commonly developed on the eastern side of the mapped area so that there is a pronounced asymmetrical profile of preserved sediment packages. The asymmetry is accentuated by the uplifted and truncated units at the eastern margin of the basin.

4. The asymmetrical profile, demonstrated by the isopachs for this interval, clearly reflects the major structural divisions (Comet Ridge, Taroom Trough, Auburn Arch) described from the area by Dickins & Malone (1973) and Exon (1976).

5. The distribution, and variation of subsurface geometry and facies in the units of this division across the area indicates that there is a close connection between the development of the major structures and history of sedimentation.

The sediment packages thicken off the Comet Ridge eastwards into the Taroom Trough (Fig. 6) with several separate depocentres in areas near the Auburn Arch and towards the Burunga Fault. A sediment thickness equivalent to about 2000 ms is indicated in this region, and on line T82-L-7 (Fig. 5) the Back Creek and Blackwater Groups attain almost 3000 m, calculated using rms velocities. A decrease in isopach gradient, with comparatively widely spaced contours in a broad meridional zone, is commonly developed between the axis of the Mimosa Syncline and the depocentres towards the eastern basin margin, in the Taroom Trough area. The precise reason for the presence of this zone of much diminished rate of sediment thickness increase in an easterly direction is not readily apparent. The disparity between the two position of the two structural axes indicates that the Late Triassic folding of the sediments was independent of the position of the main depocentre axis in the Taroom Trough.

'Mimosa Supergroup' (Rewan Group, Clematis Group & Moolayember Formation: S22-B33)

The isopachs for the preserved Permo-Triassic 'Mimosa Supergroup' (Fig. 10) show the following regional features:

1. A regional north-easterly to easterly increase in sediment thickness.

2. A meridional depocentre lying east of, and adjacent to, the trace of the Mimosa Syncline.

3. Steep isopach gradients and pronounced thinning towards the

eastern edge of the Taroom Trough.

4. Thin 'Mimosa Supergroup' preserved in the western Taroom Trough and Comet Ridge area.

5. There is evidence in this region for thinning both by decreased depositional thickness and/or by erosion with the generation of unconformity surfaces in both areas, to the east and west of the Taroom Trough.

Maximum indicated thicknesses calculated along three seismic lines is as follows: T82-L-102, 5100m; T83-WA-09, 6600m; T83-WA-06, 7300m.

The sediment thicknesses indicated for the 'Mimosa Supergroup' are strongly influenced by erosion mainly in the eastern part of the area, unlike those for the Blackwater and Back Creek Groups. This geometry exists primarily because of the major Late Triassic uplift and erosion prior to Jurassic sedimentation of the Surat Basin (see Lines 83-52/8, Fig. 7, Line T82-L-2, Fig. 13, and the fence diagram, Fig. 12). The strongest uplift and erosion in the area occurred in the region of the Auburn Arch, and extended to a lesser degree across the whole Late Triassic surface. The interpreted seismic lines showing the basal unconformity in this area (fence diagram, Fig. 12) illustrate the amount of erosion that has occurred. The thickness of sediment removed by erosion decreases rapidly westwards as the distance from the eastern edge of the Bowen Basin increases, so that it is at a minimum either at or near the axis of the Taroom Trough. There is also an indication of depositional thickness decrease towards the Auburn Arch which may indicate a depositional edge in this direction and possibly structural growth during sedimentation. Some of the units and sequences show evidence of thinning to the east whereas others do not. Similarly some sequences, such as the basal Moolayember unit and top Clematis unit, show thinning over the Tiggrigie structure in the south-west, indicating intermittent structural growth.

Hence the top of the 'Mimosa Supergroup' is an erosion surface and the isopachs indicate only the preserved remnant of the 'Supergroup'. It is difficult to gauge the extent of erosion in the centre of the Mimosa Syncline where the minimum thickness of sediments has been removed. Seismic sections across this part of the basin (e.g., Fig. 6) show no apparent discordance between reflectors below and above the base Surat Basin unconformity. However, the interval represents a hiatus spanning at least the whole of the Late Triassic and it seems unlikely that the surface would remain unaltered over this length of time. In addition the detail recorded on the seismic section is not sufficient to resolve the fine details of erosion that may be present at the junction of parallel strata at an erosion surface.

The preserved maximum thickness of sediments now lies near the middle of the mapped area in a broad (about 20 km wide) meridional band and corresponds approximately in position to the meridional zone of uniform thicknesses indicated by the isopachs drawn for the Blackwater and Back Creek Groups. The reason for the correspondence is a combination of the effects of erosion and structural history of the region. The coal measures were modified by erosion before the Permian - Middle Triassic 'Mimosa Supergroup' was deposited, so that the position of the depocentre axis is no longer certain. Similarly, the eastern edge of the 'Mimosa Supergroup' was strongly modified and the trend and parallelism of the two features in the isopached intervals appear to be a coincidence of structural uplift and the

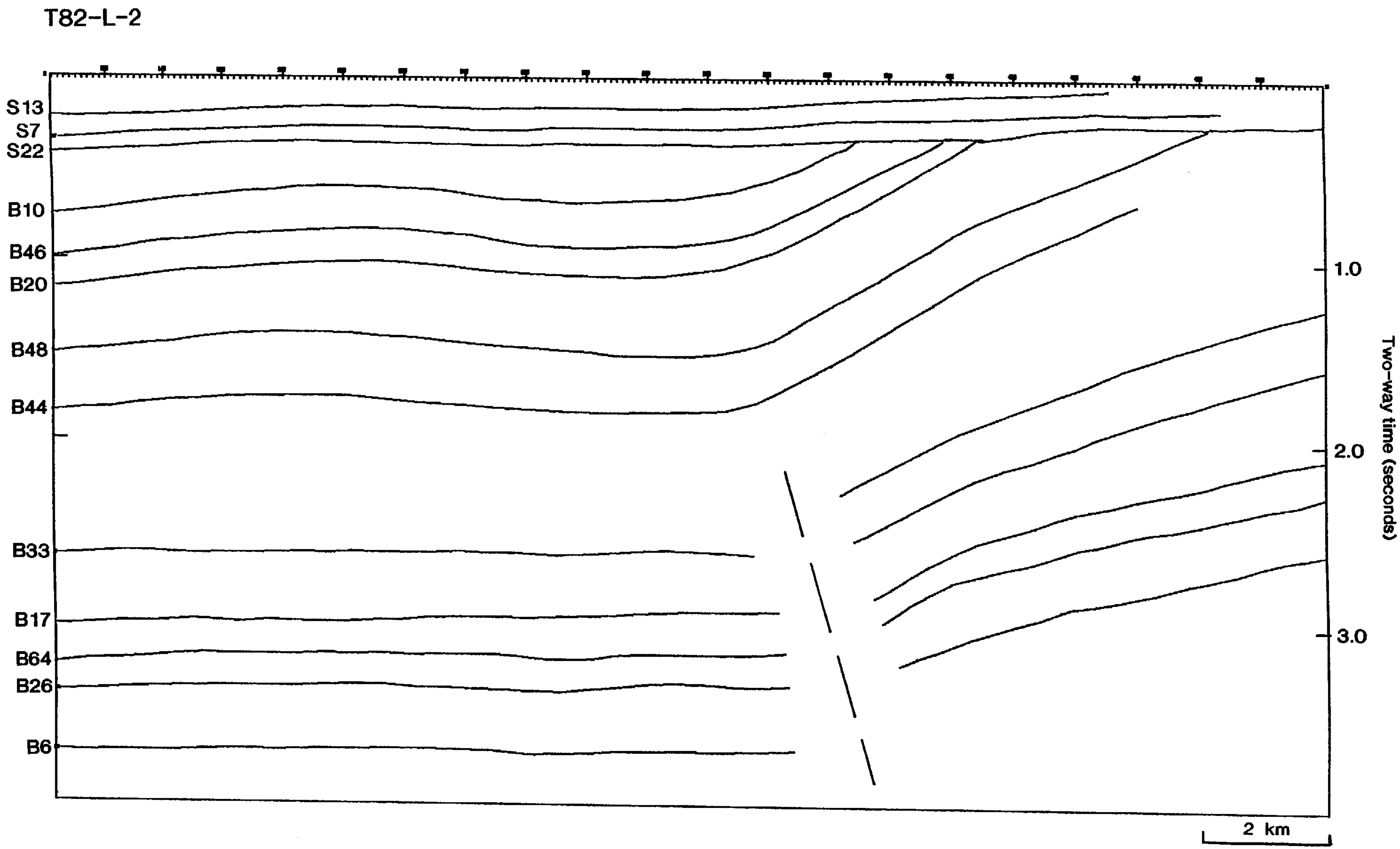


Fig. 13. Interpreted geology along seismic line T82-L-2.

amount of erosion. The depocentre of the 'Mimosa Supergroup' was mostly removed and the locus of the preserved maximum thickness moved westwards away from the Auburn Arch. The steep gradients to the east of the preserved maximum thickness are caused by major uplift and erosion of the 'Mimosa Supergroup' towards the Auburn Arch and the Burunga Fault; this feature is less pronounced in the deeper sediments.

Two minor reversals of the steep easterly gradient occur at the southern part of the isopached area. These depocentres are structural in origin and reflect small packages of sediments in the Bowen Basin preserved in eroded folds beneath the Jurassic unconformity.

The presence of depocentres in the basal part of the 'Mimosa Supergroup' on the eastern side of the Taroom Trough at the level of the lower Rewan (B44-B33) interval suggests that the 'Mimosa Supergroup', considered as an entity, probably had a similar distribution. The depocentre lying to the east of the Mimosa synclinal axis (mapped both at the surface and at a slightly different position at the lower Rewan Group level from seismic structure contours) would then correspond with the broad meridional trending zone of low isopach gradients shown on deeper units. This distribution of sediments in the Taroom region would suggest that a depositional edge for the 'Mimosa Supergroup' lay to the east. In addition, the main provenance for the Late Permian - Triassic sediments here was probably in the area of the Auburn Arch.

A summary of cross-stratification trends in the units of the 'Mimosa Supergroup' is given by Jensen (1975), who discussed the trends in terms of his subdivisions of the Rewan Group, the Sagittarius Sandstone overlain by the Arcadia Formation, and the younger Clematis Group, composed of the Glenidal Formation overlain by the Expedition Sandstone. The relationship of Jensen's formations to the sequences and sequence boundaries recognised in the Taroom region is, as yet, unknown. The sediment dispersal patterns between these units within the 'Supergroup' are noticeably different (see Jensen, 1975, figs 76-81). In the Taroom region, the palaeocurrent directions for the Arcadia Formation and Glenidal Formations are consistent with the postulated easterly derivation of sediments. The palaeocurrents for the Expedition Sandstone are north to south in the Taroom region, with easterly-directed palaeocurrents indicated by cross stratification in outcrop on the western flank of the Mimosa Syncline. However, they do not entirely rule out the postulated existance of provenance areas in the east. The south-directed sediment transport direction could indicate a different basin palaeogeographic setting during deposition of this sandstone so that both easterly and westerly directed feeder streams could have supplied detritus to the principal axial drainage system which had a meridional trend. Alcock (1970) indicated that palaeocurrent directions for the Moolayember Formation were also approximately southward-directed with provenance areas in the north and east.

Surat Basin (Precipice Sandstone, Evergreen Formation, S22)

The isopachs for the Jurassic Surat Basin sediments are about the same (relative to the selected datum plane) as the structure contours for the base of the Precipice Sandstone (S22, base of Surat Basin, see Fig. 16 below) and show the following regional features:

1. A preserved, gently folded, wedge of sediments symmetrically disposed approximately around the axis of the

Mimosa Syncline.

2. A maximum thickness of preserved sediments of 740 ms at the southern end of the Mimosa synclinal axis in the mapped area, corresponding to a thickness of about 1200 m of sediments (calculated from rms velocities on seismic line C81-38).

It is important to emphasise that because the Surat Basin sediments are exposed in eroded folds, the contours on the S22 interval show only the preserved thickness (relative to the arbitrary datum) of the Jurassic Surat Basin sediments in the Mimosa Syncline. The Late Jurassic and mid-Tertiary movements caused broad tilting to the south and west according to Exon (1974) and hence the preserved sedimentary succession increases in thickness southward in the direction of plunge of the Mimosa Syncline. The contours are approximately symmetrically disposed around the synclinal axis, reflecting the broad structure contours of the basal Surat Basin unconformity.

An indication of the original sediment distribution and geometry is given by isopachs on individual units in the preserved Surat Basin taking into account the eroded edge effects. Isopachs on the Precipice Sandstone (S7-S22) show no coherent trends across the mapped area - an almost random distribution of thin and thick sediment 'closures' occur across the region. The thickest pod of sediment is ~90 ms near the northeastern part of the contoured area which is equivalent to a thickness of about 130 m. Isopachs on the basal unit of the Evergreen Formation (S13-S7) show a somewhat similar distribution, but the depocentre with an equivalent of ~130 ms of sediment, in this case, occurs in the northwest; a thickness of about 180 m was calculated for this interval on seismic line C83-GL-06.

Isopachs on the basal units within the Surat Basin succession show no clear indication of a regional trend in the central part of the mapped zone. The units thin both to the east and west which suggests that structure in the basement was still influencing deposition of the Jurassic sediments because a proportion of this thinning is independent of the effects of erosion at the exposed edges. There is no well defined trend to the depocentres for the individual units and this lends little supporting evidence for the influence of the basement on sedimentation suggested above.

STRUCTURAL CONFIGURATION AND TECTONIC DEVELOPMENT OF THE BOWEN AND SURAT BASINS IN THE TAROOM REGION (JMT & RJK)

STRUCTURAL GEOMETRY

A series of 13 structure contour maps (in two-way travel time) have been produced within Petroseis^{TM} (see Appendix 1) based on the regional network of interpreted seismic lines, and have been printed at a scale of 1:250 000. These maps show the present day geometries of the interpreted sequence boundaries and seismic horizons.

The main geological structure in the study area is the Mimosa Syncline, a nearly-meridionally trending syncline that is dominant in most of the structure contour maps and which is generally asymmetrical for the Bowen Basin succession, except at the lowermost structure contour level (B6, approximate base of Buffel Formation).

At the base of the Permian sedimentary succession (B6, Fig. 14), the Mimosa Syncline is elongate and almost symmetrical, with closure around its deepest point at 25°45' (>3900 ms). In the west, the B6 reflector dips approximately 12-15° to the east, whereas in the east it dips about 8° to the west (dips were calculated after converting two-way times to depths using rms velocities). Upwards, the syncline becomes increasingly asymmetrical, with the dips on the eastern limb being steeper than those on the western limb throughout the Permian and Early Triassic succession, as seen in the isometric projection (Fig. 11).

For the rocks deposited towards the end of the Permian, the depression (the lowest point in the syncline) is located farther north at approximately 25°25'. At the base of the Rewan Group (B33, Fig. 15, and within it (B44), the depression is elongate, with the deepest area being between about 25°10' and 25°45' (2700-2800 ms); the syncline is markedly asymmetrical, the eastern limb dipping more steeply than the western limb. For example, the B33 reflector dips approximately 10° in the west and 28° in the east, and the B44 reflector dips approximately 12° in the west and 25° in the east.

The structure contour maps of reflectors from the Clematis Group and Moolayember Formation (listed in Appendix 1) show that the depression extends slightly southward: from 25°35'-25°45' (1800 ms) at B48 to 25°25'->26°00' (1000 ms) at B10.

The structure contours on S22 (Fig. 16) show that the base of the Surat Basin succession is a broad, symmetrical syncline plunging to the south of the study area and shallowing to the north to where the unconformity is exposed in outcrop.

To the east of the strongly tilted eastern limb of the syncline, in the southeastern part of the study area, there is a flattening of the structure contours (from B6 to B44). This can be seen readily in the isometric projection of the B17 reflector (Fig. 11).

Dickins & Malone (1973, p.93) considered that "The Mimosa Syncline is mainly an unfolded depositional downwarp." However, dips of 25-30° on the eastern limb of the syncline are too steep for a depositional slope or even for one altered by compaction and later differential subsidence; we consider that this steepness resulted from movements during the Middle to Late

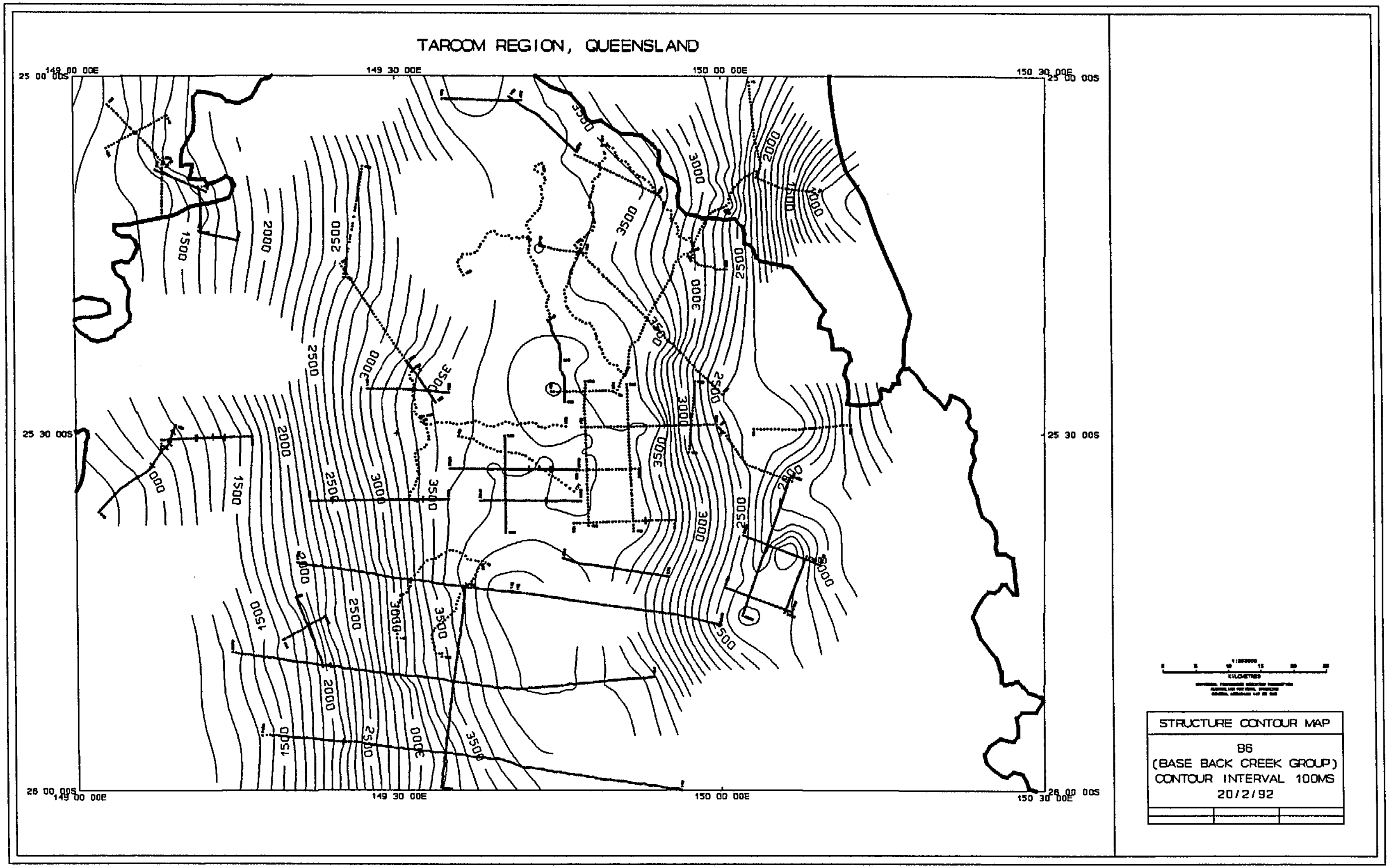


Fig. 14. Structure contour map in two-way time of B6 reflector (approximately equivalent to the base of the Back Creek Group).

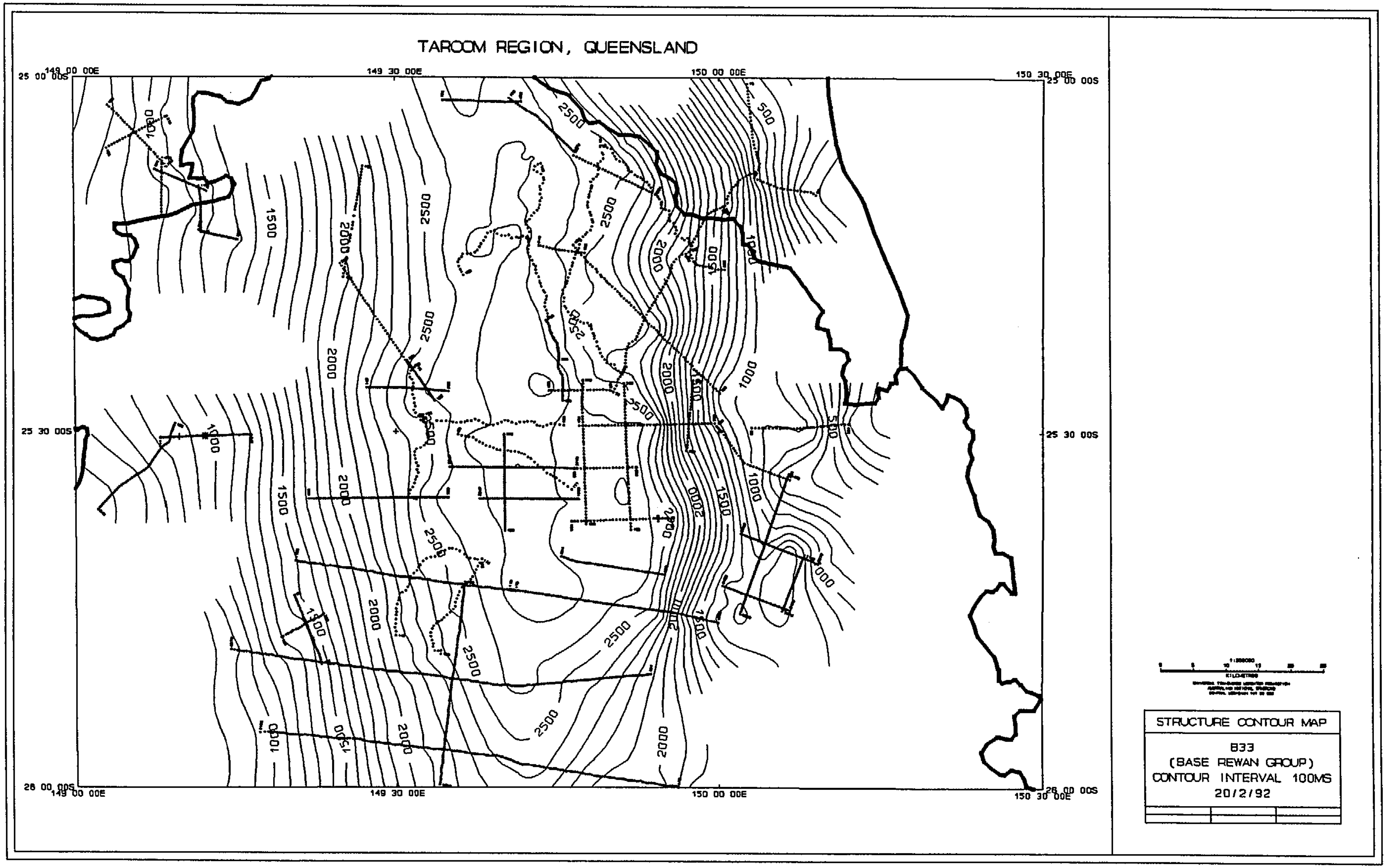


Fig. 15. Structure contour map in two-way time of B33 reflector (approximately equivalent to the base of the Late Permian coal measures).

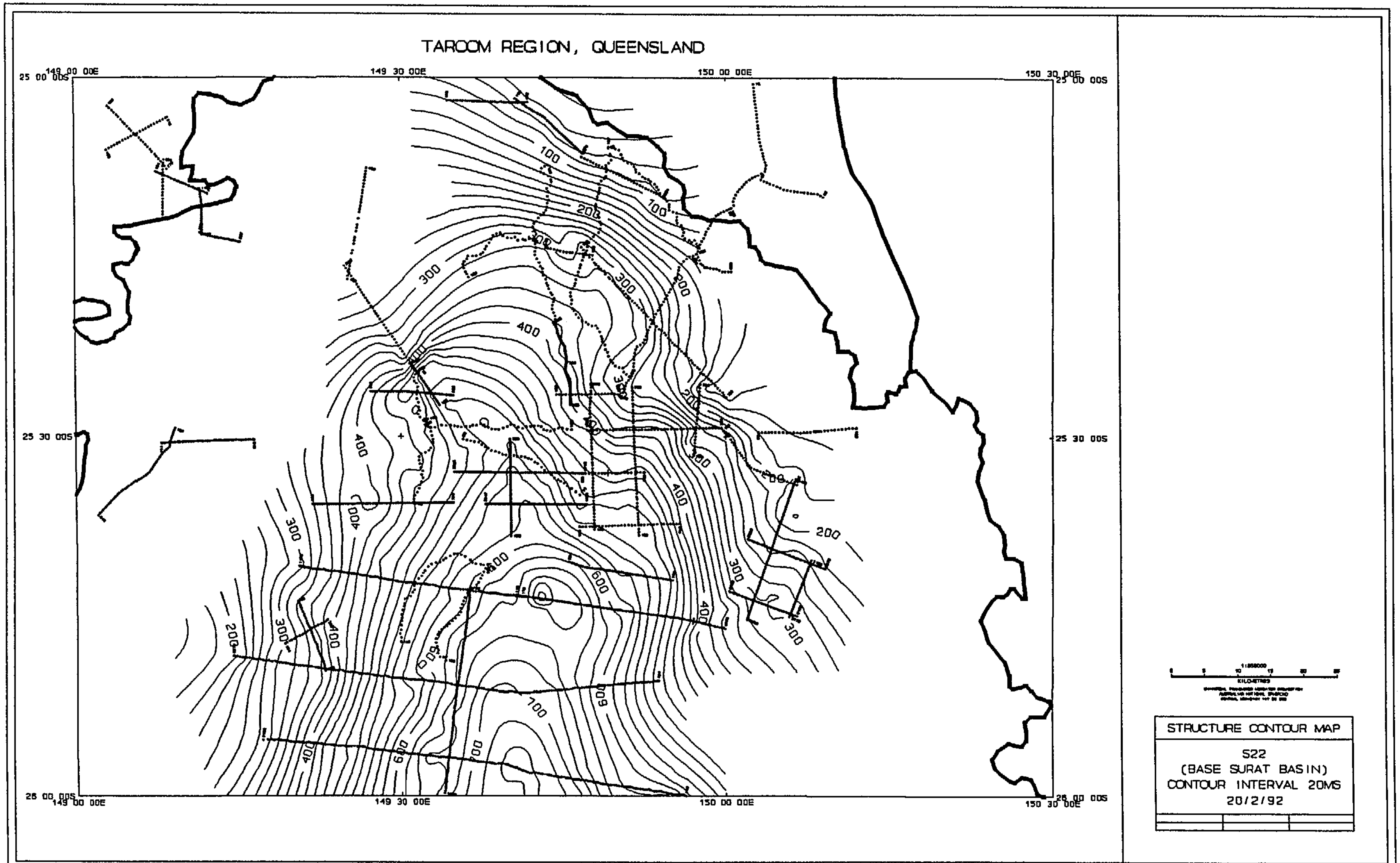


Fig. 16. Structure contour map in two-way time of S22 reflector (base of the Surat Basin succession).

Triassic on thrust faults in the eastern part of the basin. Also, the depositional axes (the axes of greatest two-way time in the isopach maps, which are equivalent to the the areas of maximum thickness) for individual sedimentary packages do not coincide with the axes of the Mimosa Syncline (the axes of maximum two-way time shown on the structure contour maps). For almost every sequence or package, the axis of maximum deposition is located 10-25 km to the east of the synclinal axis of the relevant structure-contoured horizon. This indicates that the structure contours east of the synclinal axis reflect a deformational event, and that the present geometry in this area is not related to the depositional history of the basin.

The Mimosa Syncline should not be regarded simply as an asymmetric fold with two tilted limbs. The western limb, with shallow dips of up to 15° probably represents the original depositional position which has been modified during subsidence and compaction; it is unlikely to have been tilted much during deformation. The eastern limb of the syncline was produced as a response to thrusting on the eastern margin of the basin, with dips of up to 30° resulting from the beds being transported up a west-dipping ramp (see below).

The axes of maximum two-way time for the structure contour maps are remarkably coincident from one map to another, whereas for an asymmetric fold with a short eastern limb, the position of the axis should migrate towards the west upwards through the fold stack. This may be an artifact resulting from using unmigrated seismic data (see McQuillin & others, 1984); when the data are migrated, the line containing the hinge points may migrate away from the vertical to show a tilted axial surface trend.

STRUCTURES

1. Small half-graben

In the southwestern part of the mapped area, a small half-graben occurs at the base of the succession on line C81-T-38 (SP 1740), suggesting an early phase of extension. The half-graben is bounded on the western side by an east-dipping normal fault on which there has been approximately 350 m of horizontal extension. It contains approximately 350-390 m of fill. In this area, the B6 reflector is not clearly imaged and, although it is possible that this reflector has been displaced by the fault, it is more likely that it is immediately above the half-graben. This implies that the half-graben fill is equivalent to the Reids Dome beds in the Denison Trough to the west.

2. Minor extensional faults in the west

On the western side of the Mimosa Syncline the sedimentary rocks shallow gradually onto the Comet Ridge. There is some minor extensional faulting on lines T83-FV-01 and -02, in the lowermost part of the Permian sedimentary succession. Throws of up to 50 m occur at the B6 level. Nevertheless, in general, faulting is not common.

A basement high, which could be possibly fault-bounded, occurs beneath the Bowen Basin succession near the Tiggrigie Creek 1 well. Unfortunately, the seismic data quality at this depth is too poor to allow analysis of this structure.

GEOMETRY OF THE EASTERN MARGIN OF THE BOWEN BASIN

In the study area, the eastern margin of the

Taroom Trough is defined by the Burunga Fault, which forms part of a much larger fault system, the Burunga-Leichhardt-Moonie-Goondiwindi-Mooki-Hunter-fault system (Fig. 1). Power & Devine (1970) suggested that the Burunga-Moonie-Goondiwindi part of the fault system was a major normal fault with downthrow to the west. Exon (1976) considered that the faults were part of a thrust fault system. This high angle reverse fault interpretation strongly influences current thinking: see, for example, Thomas & others (1982); Elliott & Brown (1988); Elliott (1989); Fielding & others (1990); Finlayson (1990); Finlayson & others (1990a, 1990b).

An alternative interpretation that the fault system was extensional and listric in character was presented by Wake-Dyster & others (1987), principally to provide a mechanism for the large amount of subsidence and accumulation of a thick sediment pile in the Taroom Trough compared with that to the east of the fault system.

Deep seismic reflection surveys have now been carried out at three locations across the Sydney-Gunnedah-Bowen basin system:

1. Across the Bowen Basin farther to the north in the vicinity of Blackwater. At this latitude (approximately 23.5°S), seismic line BMR89.B01 shows that the succession within the basin, as well as the eastern margin, is dominated by east-dipping thrust faults with west-directed thrust movements (Korsch & others, 1990c).

2. In southernmost Queensland to the south of the present study area (about 27.1°S), seismic line BMR84.14 shows the Taroom Trough to be an asymmetrical trough bounded to the east by a steeply-dipping fault, the Leichhardt Fault. Korsch & others (in prep.) interpret this fault as a planar fault which dips very steeply to the west; they consider that the basin was initiated by an oblique extensional mechanism.

3. In the Gunnedah Basin in New South Wales at about 30.7°S, preliminary geological interpretation of seismic line BMR91.G01 by Korsch & others (1992) suggests that the Mooki Fault is a low-angle thrust fault on which the Tamworth Belt has been thrust westwards over the eastern margin of the Gunnedah Basin. There is virtually no internal deformation of the Gunnedah Basin by thrusting.

These three seismic traverses show totally different seismic images of the eastern margin of the Bowen-Gunnedah-Sydney basin system, indicating that the eastern margin is extremely complex, and that its character changes along strike.

Seismic lines in the eastern part of the Taroom region show a different geometry again, with a considerable amount of tilting of the Bowen Basin succession beneath the Precipice Sandstone of the Surat Basin (e.g. lines T82-L-2 and 83-52/8, see Figs. 13, 7). The Bowen Basin succession now dips up to 30° to the west and a classic angular unconformity is the result (Figs 7, 13). In the Taroom region, up to 4400 m of the succession has been eroded and in the east the Precipice Sandstone sits directly on the Rewan Group and possibly on the Baralaba Coal Measures. This monocline is the dominant structure of the Taroom region and traditionally has been regarded as the eastern limb of the Mimosa Syncline. Unfortunately, the seismic coverage in the Taroom region does not extend as far east as the position of the inferred bounding fault, the Burunga Fault. Hence the geometry of the eastern margin is, to some extent, unconstrained in this area.

The eastern margin has been interpreted as a reverse fault dipping very steeply to the east (e.g. Thomas & others, 1982; Elliott & Brown, 1988). Seismic sections figured by these authors from south of the Taroom region show virtually no evidence for the tilting seen in the Taroom region. Mechanically, it is very difficult to envisage enough drag on a fault to uplift the rocks in the lower plate sufficiently to enable in excess of 4.4 km of stratigraphic succession to be removed. This implies also that much greater than 4.4 km has been removed from the upper plate to the east of the fault (Fig. 17a).

A second possibility is that the Burunga Fault in the Taroom region dips steeply to the west. During basin initiation it could have been an extensional fault bounding a half-graben (the Taroom Trough). During later thrusting, the fault could have been reactivated, and the Taroom Trough became inverted adjacent to the fault (Fig. 17b).

We present here two alternative interpretations for the observed geometry of the eastern margin in the Taroom region which suggest that the Taroom Trough was part of the upper plate during thrusting. The tilting and uplift was controlled by a thrust fault with a flat-ramp-flat geometry that occurs beneath the sedimentary succession. At least two main variations on this geometry are possible:

1. West-dipping ramp

The sedimentary succession could have formed part of the upper plate above a thrust fault which had a ramp and flat geometry (Fig. 17c). During east-directed thrusting, the succession would become tilted as the upper plate moved up the ramp. The ramp geometry could convert upwards and eastwards into a flat. The dips of the beds in the upper plate would then flatten above the flat. This is consistent with the geometry observed in the structure contour maps (e.g. Figs 11, 14, 15). Nevertheless, this hypothesis contains the implication that the thrusting was east-directed and that any foreland loading (and hence subsidence) resulting from the thrusting would occur above and to the east of the ramp. Major subsidence to the east of the inferred fault position is not observed in the sedimentary record, however, which shows that the locus of subsidence was located to the west.

2. Duplexing in triangle zone and backthrusting

If the thrusting was predominantly west-directed and located to the east of the present basin margin, the ramp and flat geometry could be part of a back thrust at the base of, or just below, the sedimentary succession. This would require a large triangle zone (such as that produced by an anticlinal stack or duplex structure) to "jack up" the crust and produce the tilting seen in the Taroom region (Fig. 17d).

In this hypothesis, duplexing of the basement to the east (the Auburn Arch - a Devonian to Late Carboniferous magmatic arc) is implied. The hard, rigid Auburn Arch was unable to be thrust over the Taroom Trough. Hence an east-directed backthrust developed and thrust the trough sediments over the Auburn Arch. The dominant thrusting, however, would be west-directed in the basement to the east. It is possible that the Burunga Fault could represent the eastern limit of this west-dipping backthrust. Alternatively, it could represent one of the east-dipping thrusts in the basement.

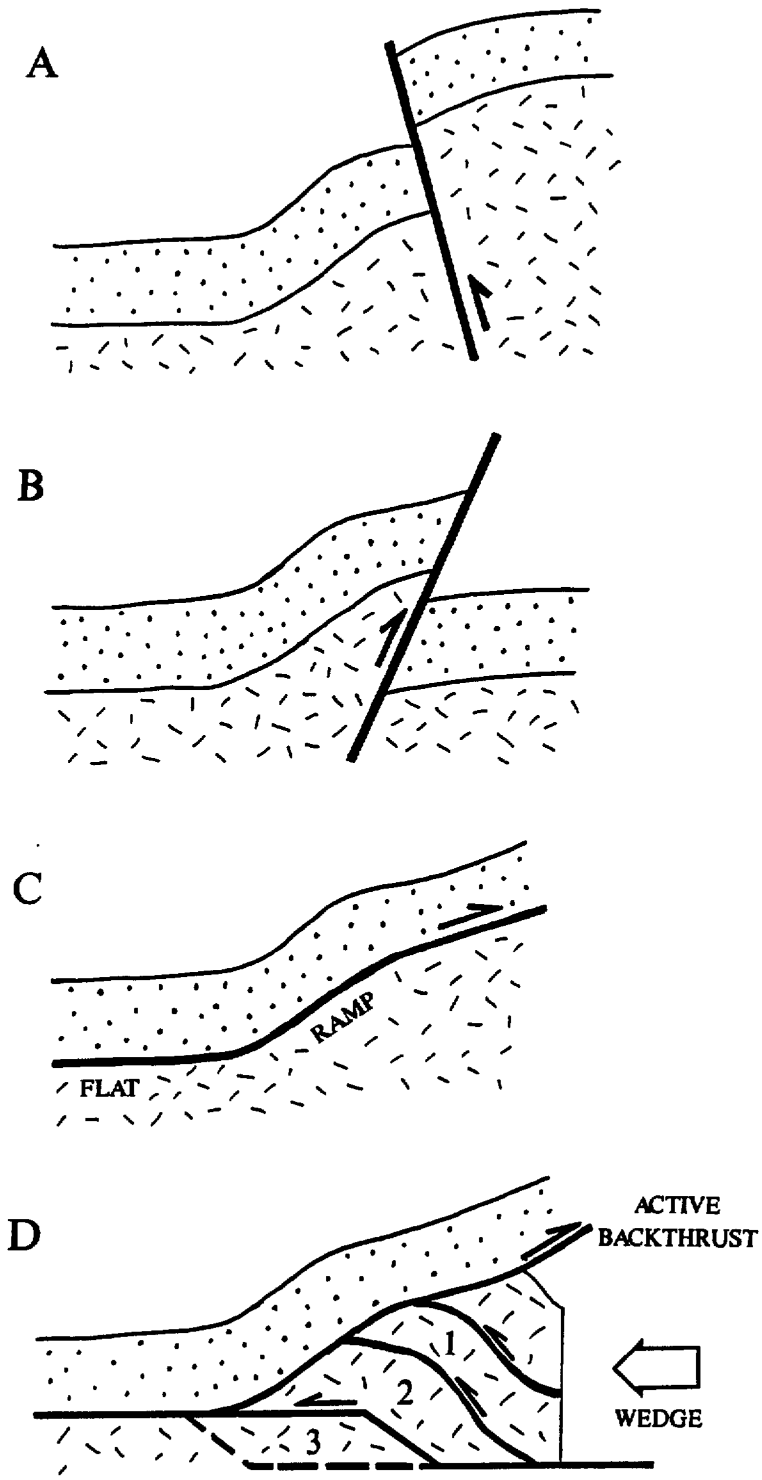


Fig. 17. Cartoons to illustrate some possible geometries for the eastern margin of the Taroom Trough in the Taroom region.

a. High-angle reverse fault with the Taroom Trough on the lower plate (footwall).

b. High-angle reverse fault with the Taroom Trough on the upper plate (hanging wall).

c. East-directed thrusting with the thrust fault having a ramp-flat geometry.

d. Duplexing in the basement during west-directed thrusting, with the Taroom Trough being associated with a higher level east-directed backthrust (modified from Roure & others, 1990).

Backthrusting in sedimentary successions above duplex structures in either the succession or in the basement appears to be a very common geometry and has been reported from many areas (e.g. European Alps - Roure & others, 1990, Stäuble & Pfiffner, 1991; Wales - Jones, 1991; Greenland - Soper & Higgins, 1990; Newfoundland - Cawood & Botsford, 1991; Alberta - Skuce & others, 1992; Argentina - Viñes, 1990; central Africa - Daly & others, 1991)

Four possible geometries for the nature of the eastern margin of the Taroom Trough in the study area are presented in Figure 17. Although we favour the last alternative, conclusive evidence is lacking for any of the hypotheses. Work to the south of the Taroom region, where the seismic coverage is more extensive, may shed some light on the problem, but possibly it will be resolved only by a deep seismic reflection traverse oriented east-west across the eastern margin in the Taroom region.

3. Minor thrust faults

A west-dipping thrust fault affects Permian and Triassic sediments in lines S84-CT-02 (Fig. 4) and S84-CT-08. Approximately 340 ms of displacement (about 750 m) has occurred. This fault is located about 15 km to the west of the inferred position of the Burunga Fault (Fig. 2) and occurs to the east of the tilting discussed above; it is possible that the thrust is a splay off the Burunga Fault.

There is some evidence of faulting at the inflexion point between relatively flat-lying or gently dipping strata and more steeply inclined sediments on the eastern limb of the Mimosa Syncline on lines T82-L-2 (Fig. 13) and T82-L-110. It is possible, however, that the structuring seen in the sediments is a result of local accommodation caused by a ramp and flat geometry of an underlying thrust fault (Fig. 18). If this were the case, the thrust would be a small backthrust to the main backthrust, possibly the Burunga Fault.

One possible geometry that could link the minor thrusts to the main thrust is the fault-bend fold mechanism described by Suppe (1983). Minor thrusting could occur in contractional areas as the upper plate moves over a ramp in the main thrust (see fig. 18).

TECTONIC DEVELOPMENT

Tectonic subsidence curves

Subsidence patterns in sedimentary basins result from a combination of mechanical and thermal processes such as crustal thinning (due to stretching), crustal thickening and loading (due to shortening by thrusting) and thermal cooling. The subsidence history of a basin caused by one or a combination of these mechanisms can be examined by constructing subsidence curves from stratigraphic data.

Tectonic subsidence curves, constructed by the backstripping technique (as described by Sleep, 1971; Watts & Ryan, 1976; Steckler & Watts, 1978; Sclater & Christie, 1980; Ungerer & others, 1984; and many others), provide valuable information on basin evolution, because they attempt to remove the effects of processes such as sediment loading, loading due to the water column, sediment compaction and eustatic sea-level changes. Thus these curves attempt to show the subsidence that would have occurred as a result of tectonic processes alone. A major benefit is that they can provide an indication of the origin of the basin, even if the shape of the basin has changed due to subsequent deformation or erosion.

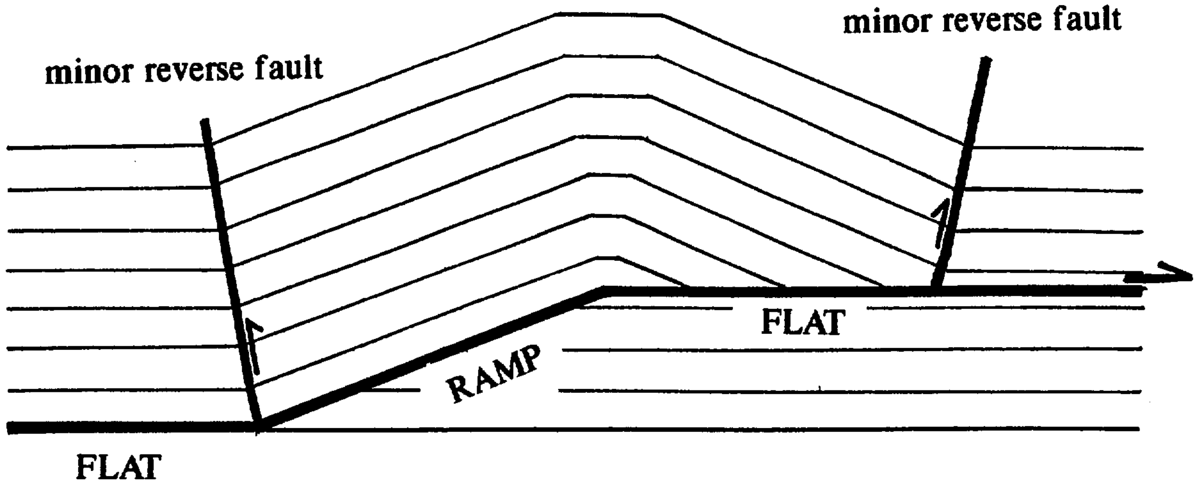


Fig. 18. Model of a fault-bend fold (after Suppe, 1983) to illustrate the geometry of the upper plate as it passes over a ramp in a thrust fault. Minor thrusting can occur in two main positions in the upper plate.

Stretching (extensional) basins and shortening (foreland) basins have distinctive subsidence curves that are useful in understanding the evolution of complex sedimentary basins; stretching basins have curves that are predominantly concave up whereas shortening basins have curves that are predominantly convex up. Thus the curves can be used as a predictive tool to infer the nature of the thermal and/or mechanical processes that operated at different stages during basin development.

In constructing tectonic subsidence curves for the Taroom region, we have not considered eustatic sea-level fluctuations. Apart from some units in the Permian, most of the sediments were deposited under continental (fluvial to lacustrine) conditions. Units older than the Late Permian coal measures were deposited under mostly deltaic-paralic to shallow marine shelf conditions and the palaeobathymetry for them is taken as 10-50 m. The effects of eustatic sea-level changes on the computed tectonic subsidence curves would be small, and despite not considering them, the general shape of the computed curves will still be valid qualitatively (cf. Heidlauf & others, 1986). Parameters for the relationship between porosity and depth are taken from Sclater & Christie (1980).

Problems with Australian Chronostratigraphy

An important factor controlling the shape of the subsidence curves is the time scale chosen. There is considerable uncertainty at present about the Australian geological time scale, particularly in the Permian and Early Triassic because of the difficulties in correlating the eastern Australian faunas and floras with those elsewhere in the world. This leads to uncertainties in applying a numerical time scale to the eastern Australian biostratigraphy. In addition, calibration of the international time scale with high resolution isotopic ages is only in its infancy and many uncertainties still exist. Current time scales show considerable variations. For example, the age of the Permian-Triassic boundary is given as 250 Ma by Haq & Van Eysinga (1987) and as 245 Ma by Harland & others (1990). New U-Pb SHRIMP dating of zircons from a Chinese bentonite by Claoué-Long & others (1991) suggests that the boundary is about 251.2 ± 3.4 (2σ) Ma. Based on U-Pb analyses on zircons from the northern Sydney Basin, Gulson & others (1990) suggested that the age of this boundary was 255 ± 4 Ma.

In contrast, the Carboniferous-Permian boundary is given as 290 Ma by both Haq & Van Eysinga (1987) and Harland & others (1990). In Germany, Hess & Lippolt (1986), using Ar-Ar dating of sanidines, have suggested that the upper limit of the Carboniferous is 300 Ma. Based on their work in the northern Sydney Basin, this age is supported by Gulson & others (1990). New SHRIMP dating of zircons from tuffs in eastern Australia by J.C. Claoué-Long suggests that here this boundary could be as young as about 275 Ma (Roberts & others, 1991).

There are also disagreements over the ages and durations of the stages within the periods. For the Permian Artinskian stage, for example, a duration of 5 m.y. is proposed by Haq & Van Eysinga (1987), whereas Harland & others (1990) propose a duration of 9.1 m.y.

Hence, considerable differences in the duration of time available for the deposition of individual stratigraphic formations are possible, depending upon which numerical time scale the individual formations are calibrated with. The best constrained ages are the SHRIMP age for the Permian-Triassic boundary (Claoué-Long & others, 1991) and the Ar-Ar age of Hess & Lippolt (1986) for the Carboniferous-Permian boundary. Hence, until a consistent Australian time scale has been developed, we have chosen to follow the time scale of Haq & Van Eysinga (1987) because this time scale is closest to the above two age determinations. We use this time scale consistently for all the tectonic subsidence curves so that individual subsidence histories can be compared. Note that this time scale produces different numerical ages for stratigraphic formations compared with the time scales used by some other workers in the Bowen and Surat basins such as Fielding & others (1990); most of the sequence boundaries used here become slightly older.

As a note of caution, until a well-constrained Australian numerical time scale has been developed, the subsidence curves should not be used for detailed interpretation, but only used as a guide to the overall subsidence history of the basin and to indicate when major changes in subsidence rate occurred.

Subsidence curves for the Taroom region

For the Permian, biostratigraphic ages for the southwest part of the Bowen Basin were taken from Archbold & Dickins (1990) and these were correlated with the numerical time scale of Haq & Van Eysinga (1987). Correlations of lithostratigraphy from the southwest part of the basin with the southeast part of the basin follow Draper & others (1990). Biostratigraphic ages for the Triassic formations follow Balme (1990) and Burger (1992), and those for the Jurassic follow Burger (1990).

Preliminary subsidence curves are presented here for four petroleum exploration wells and also for two of the thickest stratigraphic sections in the Taroom Trough within the study area. The depths for the thick stratigraphic sections in the trough were determined from seismic data, with the two-way travel time converted to depths using rms velocities. The positions are shotpoint 156 on seismic line C82-T-52 and shotpoint 131 on seismic line T82-L-102 (Fig. 2).

Because we have no constraints on the thickness of the Early Permian volcanic pile, we have used the top of this unit (reflector B6, equivalent to the base of the Buffel and Cattle Creek formations) as a common base level; all the subsidence curves commence from this horizon.

Cockatoo Creek 1

The tectonic subsidence curve for the Cockatoo Creek 1 well (Fig. 19a) shows that the rate of subsidence was initially very slow. An unconformity between the Buffel and Oxtrack formations, which has been taken into account in the subsidence curve, suggests that more sediment was originally deposited. The early slow subsidence was followed by a period of extremely rapid subsidence and sedimentation which commenced with the deposition of the Barfield Formation. Rapid subsidence continued until the Early or Middle Triassic and was followed by uplift and erosion of the eastern margin prior to deposition of the Surat Basin succession in the Early Jurassic. Approximately 4.25 km of stratigraphic section was removed at this locality prior to deposition of the Surat Basin (as indicated by the dotted line in Figure 19a).

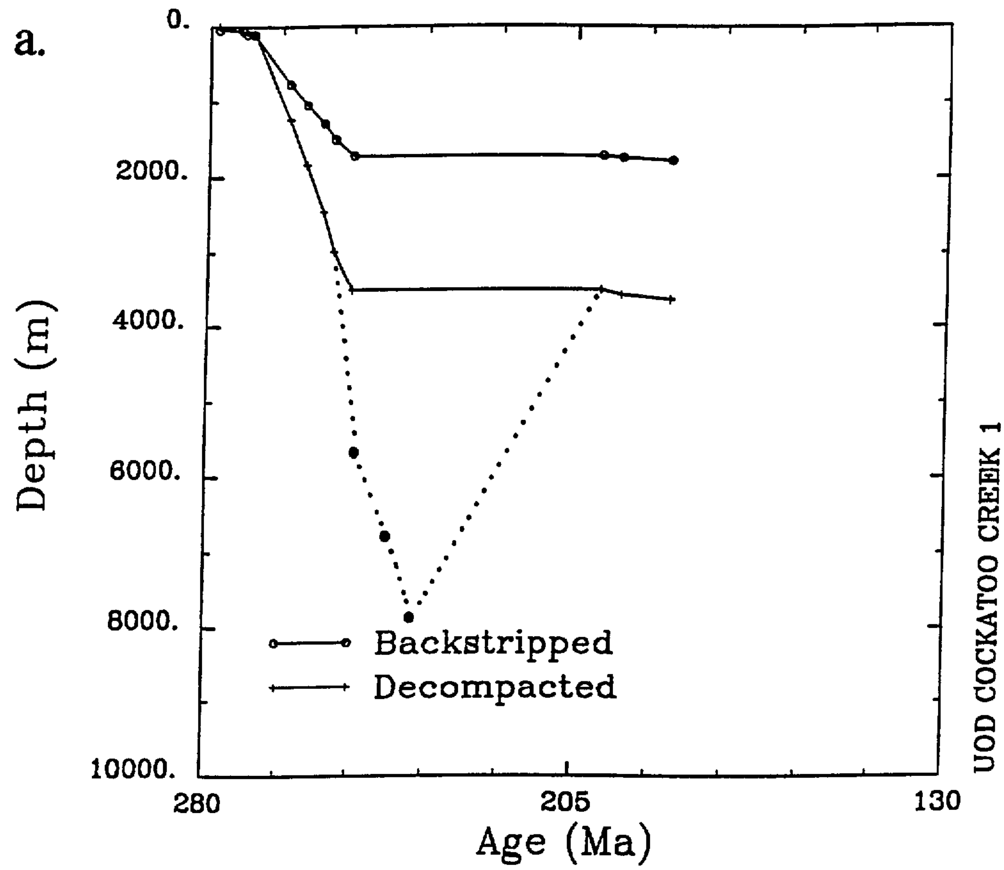
Burunga 1

This well (Fig. 19b) exhibits a similar subsidence history to Cockatoo Creek 1, although a more complete record of the Surat Basin has been preserved. Approximately 4.4 km of stratigraphic section was removed prior to deposition of the Surat Basin. One problem is that, as yet, the stratigraphic units within the Back Creek Group have not been differentiated. This group is relatively thick (about 980 m) and hence it is not possible to detect the time of commencement of the rapid subsidence phase seen in Cockatoo Creek 1, except to say that it was before the deposition of the Gyranda Formation.

Shotpoint 156, line C82-T-52 and shotpoint 131, line T82-L-102

These shotpoints represent the thickest, preserved parts of the Bowen Basin in the study area (see Fig. 2 for locations). Using rms velocities, the depth to the top of the volcanics (B6) is about 9.9 km at shotpoint 156 and about 8.7 km at shotpoint 131. Although there is a significant time break from the Middle Triassic to Early Jurassic, it is difficult to estimate the amount of stratigraphic succession that might have been removed. In the seismic sections, the youngest formation of the Bowen Basin, the Moolayember Formation, is very thick (about 1400 m at SP 156 and 1370 m at SP 131) and there is very little evidence for erosion at the top of this formation. Hence, the amount of erosion in the central part of the Taroom Trough may have been minimal.

In line C82-T-52, seismic resolution below the base of the Baralaba Coal Measures (B17) is poor, and reflectors B64 and B26 are not recognisable. In T82-L-102, no reflectors have been interpreted between the base of the Flat Top Formation (B26) and the base of the Buffel Formation (B6). This is a reasonably thick interval (about 885 m at SP 131), but it is not possible to determine whether the period of rapid subsidence commenced at or before the



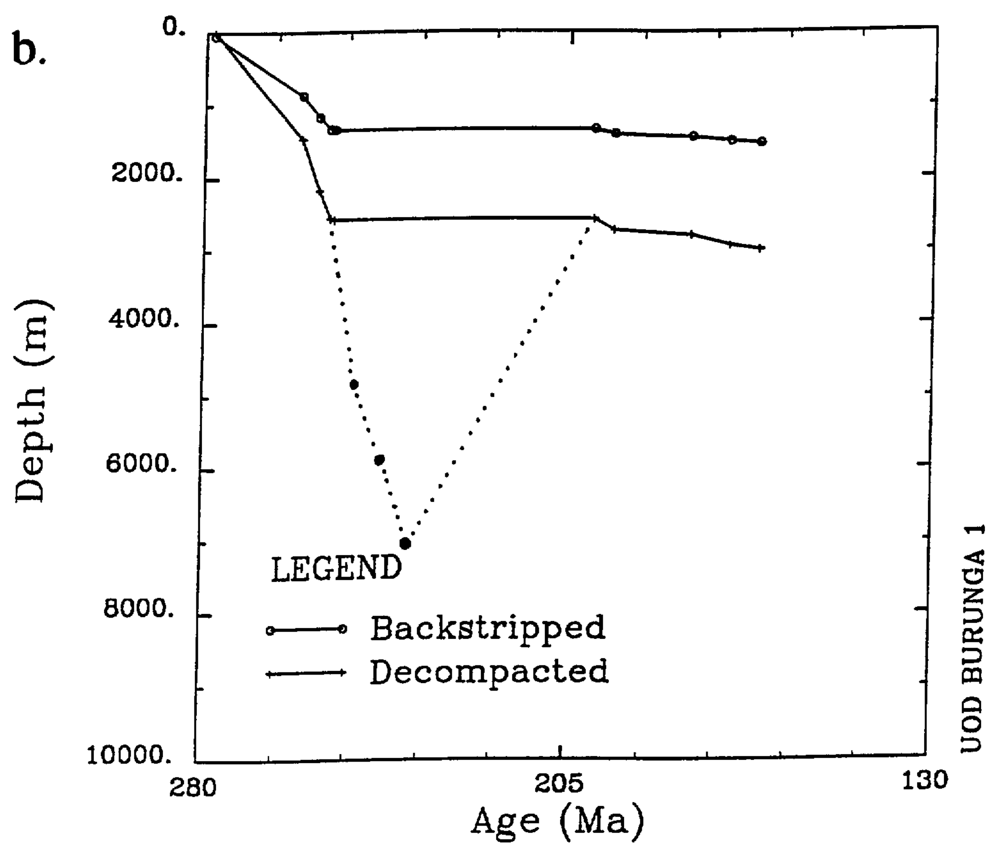


Fig. 19. Tectonic subsidence curve for (a) UOD Cockatoo Creek 1 and (b) UOD Burunga 1 wells. The dotted lines indicate an estimate of the amount of sediment that was deposited and then eroded prior to the deposition of the Early Jurassic Precipice Sandstone. This estimate is derived from the thickness of non-eroded material in the seismic sections immediately to the west.

base of the Flat Top Formation. Overall, tectonic subsidence curves for these shotpoint localities (Fig. 20a, 20b) are very similar to Cockatoo Creek 1 and Burunga 1 prior to the Middle to Late Triassic erosional event.

Glenhaughton 1

This well is located on the western margin of the Taroom Trough where the succession is thinning up onto the Comet Ridge. The early part of the Permian succession has been subdivided in some detail for only Cockatoo Creek 1 and this well; hence these wells give the best indication of the nature of the tectonic subsidence for the early part of the history of the basin. During this time interval, several unconformities (between Cattle Creek and Freitag formations, Ingelara and Peawaddy formations, and Peawaddy Formation and Black Alley Shale) suggest that more sediment was originally deposited. These unconformities have been taken into account in the subsidence curve. The initial part of the subsidence curve (Fig. 21a) has a concave-up profile which is typical of a curve due to lithospheric cooling (thermal relaxation) after a thermal event. It is not possible from subsidence curves alone to determine whether the thermal event was associated with a crustal extensional event or not.

The early exponential decay in subsidence is punctuated by a phase of more rapid subsidence that commenced with deposition of the Black Alley Shale. This is over 10 million years later than the increase in subsidence seen in Cockatoo Creek 1, over 100 km to the east-southeast.

Tiggrigie Creek 1

This well bottomed in the Gyranda Formation, but the seismic section (C83-T-4) in the vicinity of the well shows about 975 m of sediment between the base of the Late Permian coal measures (B17) and the top of the volcanics (B6). Only two individual formations below the coal measures have been distinguished on the seismic section (Gyranda and Flat Top formations). Hence, it is not possible to determine the time of commencement of the rapid subsidence phase, except to suggest that it probably occurred before the deposition of the Flat Top Formation. This well contains a good record of the Triassic sediments and the subsidence curve (Fig. 21b) is typical of all the subsidence curves through this part of the succession.

Summary of the tectonic subsidence curves

The six subsidence curves overall show a very consistent pattern, with the subsidence history subdivided into four main stages:

1. Early thermal relaxation. Evidence for this is best seen in Glenhaughton 1. Eruption of a thick volcanic pile (which could be up to several kilometres thick) in the earliest Permian occurred over a large area from the northernmost part of the Bowen Basin south into the Sydney Basin. This event, which caused elevated temperatures in the lithosphere, was followed by deposition of the Buffel and Cattle Creek formations in the Taroom region. This subsidence resulted from the thermal response following the input of heat, as represented by magma generation and volcanic activity. That is, cooling and thermal relaxation of the lithosphere drove the subsidence for about 10 m.y. after the cessation of volcanism in the eastern part of the area, and for at least 20 m.y. in the western part of the area (cf. Figs 19a and 21a).

Because there are only shallow industry

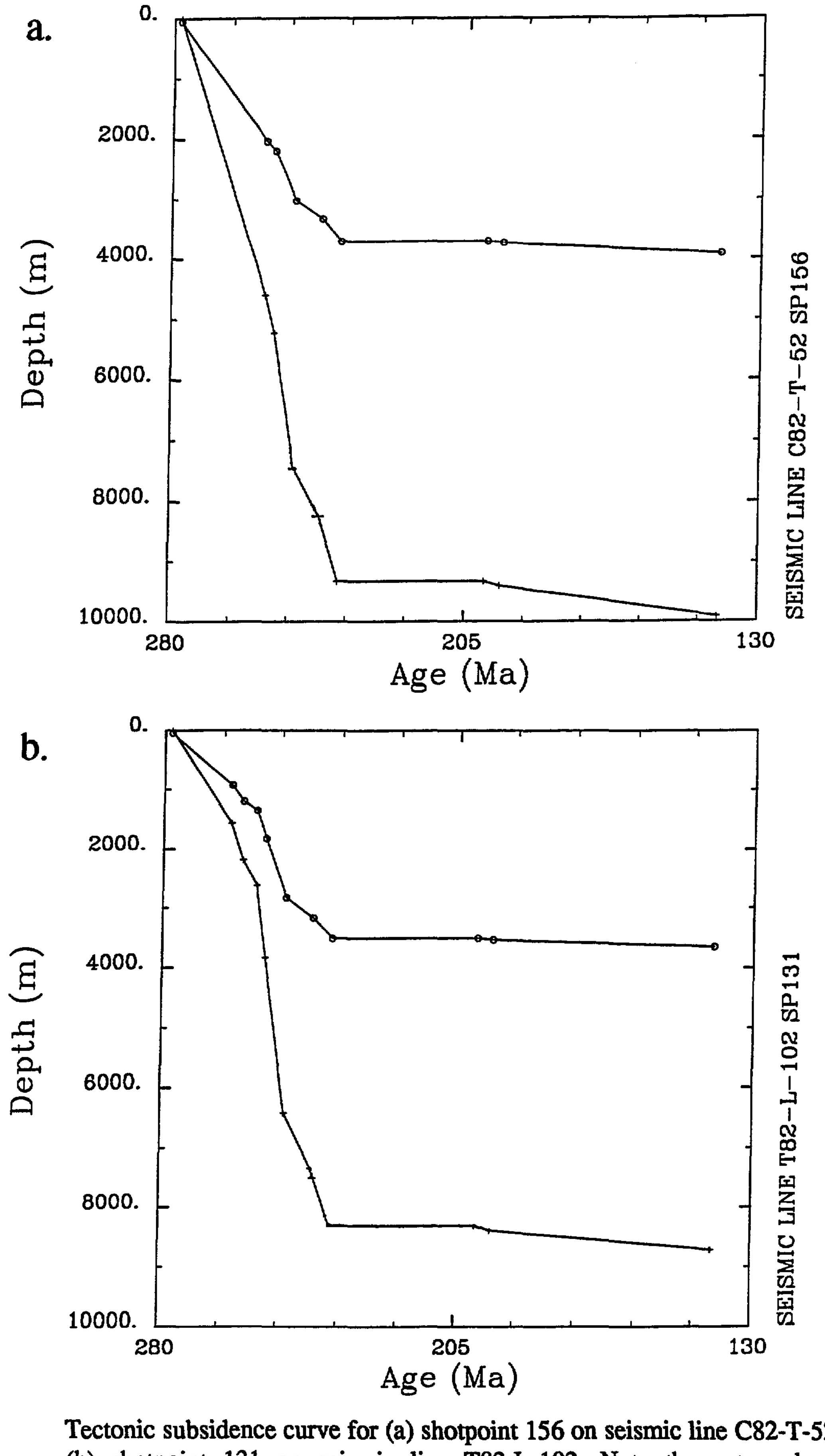


Fig. 20. Tectonic subsidence curve for (a) shotpoint 156 on seismic line C82-T-52 and (b) shotpoint 131 on seismic line T82-L-102. Note the extremely thick sedimentary successions at these localities of 9.9 km for (a) and 8.7 km for (b).

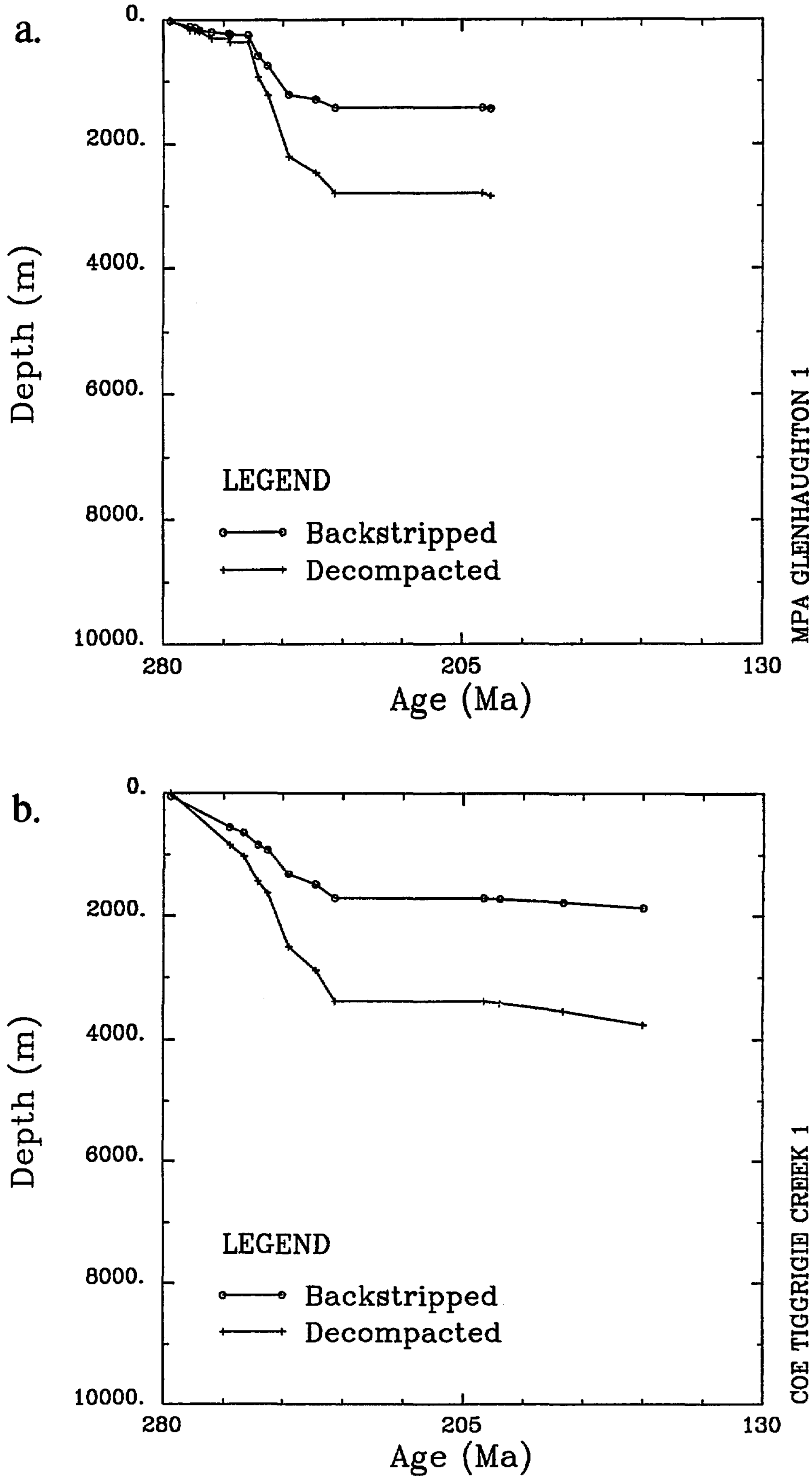


Fig. 21. Tectonic subsidence curve for (a) MPA Glenhaughton 1 and (b) COE Tiggrigie Creek 1 wells.

seismic data in the area, it is not possible to determine the geometry of the volcanic pile below the sedimentary succession. That is, it is not known whether there was active mechanical extension of the crust at the time of the eruption of the volcanics, and the question remains as to whetherthey filled a graben-like structure or not.

2. The relatively slow initial subsidence was interrupted at about 270-260 Ma by the onset of a phase of rapid subsidence which continued until the Middle Triassic, a period lasting over 30 m.y. This resulted in the deposition of a pile of sediments over 7 km thick in the central part of the Taroom Trough.

Rapid subsidence can be generated by several mechanisms, including mechanical rifting during extension, foreland loading during shortening, and transtension asociated with strike-slip faults (pull apart basins). In the New England Orogen to the east of the basin system, major deformation commenced in the 'mid' Permian at about the same time as the increase in the subsidence rate. In places, the deformation is controlled by major thrusting (e.g. Korsch & others, 1990c; Fergusson, 1990, 1991); subsidence of the basin during this stage is therefore inferred to be due to foreland loading (as previously suggested by Scheibner, 1976; Veevers, 1984). Murray (1985) suggested that the subsidence was due to loading of the crust by the magmatic arc, and Murray (1990) gives a review of the suggested loading mechanisms.

In foreland loading, subsidence is driven by thrust faults which load and thicken the crust, causing subsidence in front of the thrust sheets. In this situation, the maximum subsidence is located adjacent to thrust sheets where the load is greatest, with subsidence diminishing away from the thrust sheets; the basin shape is extremely asymmetric.

For any particular locality within a foreland basin, the rate of subsidence should increase as the thrust sheets approach. After cessation of thrusting, the sediment loading effect would produce further subsidence, but this would not be sustained for a substantial period because of the absence of any thermal recovery.

Because the thrusting was located principally to the east of the eastern margin, its effects are first noticed in the eastern part of the Taroom Trough. After the rapid subsidence phase commenced at, for example, Cockatoo Creek 1, there is a time lag of some 10 m.y. before the effects of the thrusting are felt in the western part of the area at, for example, Glenhaughton 1. That is, it took over 10 m.y. for the effects of thrusting to be propagated some 100 km to the west.

The tectonic subsidence curves (Figs 19 - 21) mostly show an increasing rate of tectonic subsidence up until the end of deposition of the Rewan Group. All curves then show a decrease in the subsidence rate during deposition of the Clematis Group. The Clematis Group is more quartz-rich when compared with the lithic sandstones of the Rewan Group below it and the Moolayember Formation above it. Deposition of the Clematis Group may represent a period of quiesence or a pause in thrusting. That is, uplift in the source area could have ceased and no new sediment was being added from the eastern margin of the basin. Derivation of the sediments from the west is supported by the palaeocurrent data of Jensen (1975). The incoming of more lithic detritus in the Moolayember Formation may represent commencement of the final phase of thrusting and foreland loading on the eastern margin of the basin.

As a note of caution, the slower subsidence rate for the Clematis Group compared with the Rewan Group and Moolayember Formation might be an artefact of the poor absolute age control due to the problems of converting from the lithostratigraphy to biostratigraphy to the numerical time scale. Nevertheless, the change in sandstone composition coupled with a significant unconformity at the base of the Clematis Group suggests that a significant change in the tectonic situation occurred at this time.

3. A period of non-deposition and/or erosion that lasted for nearly 40 m.y. This is represented by the unconformity between the Bowen Basin and the Surat Basin, which changes from a paraconformity in the central part of the Taroom Trough (e.g. Fig. 6) to a pronounced angular unconformity in the east (e.g. Fig. 7).

Cessation of sedimentation after the Moolayember Formation was deposited was caused most likely by uplift of the eastern margin due to the westward advance of the thrust sheets. Prior to this time, the deformation had been located farther to the east; hence in the Taroom region the main effect of the deformation was subsidence and input of sediment derived from the uplifted thrust sheets. By the end of deposition of the Moolayember Formation, the thrust front had advanced to the west sufficiently far to actively affect the Taroom region, causing the uplift in the eastern part of the trough.

Following cessation of thrusting, a protracted period of erosion across the entire basin produced the subdued topography on which the Surat Basin was deposited. This is reflected in the regularity of the structure contours for the base of the Precipice Sandstone (Fig. 16).

4. Subsidence recommenced in the Early Jurassic, leading to the deposition of the sediment pile in the Surat Basin. Compared with the Bowen Basin, the rate of subsidence was extremely slow. The concave up pattern of the curves suggest that the subsidence was probably driven by thermal relaxation due to cooling of the lithosphere.

CONCLUSIONS
(ATW)

Interpretation of a network of industry seismic lines in a transect across the Bowen and Surat Basins in the Taroom Trough using sequence stratigraphic techniques has indicated the presence of at least seven sequence boundaries out of thirteen mapped seismic reflectors. The succession includes both continental and marine rocks and a new approach has been the recognition and definition of sequence boundaries in both categories of rocks.

The identification and verification of sequence boundaries in the Bowen and Surat Basins relies on the recognition of a variety of stratal boundary types, and the ease of their recognition depends largely on the quality of the seismic sections. The sequence boundaries were recognised by stratal geometry (truncation, downlapping, overlapping, etc), erosional features such as channels and erosional relief, separation of packages of reflectors of different character and by other evidence of unconformities. In most cases the stratal terminations and other indicators of sequence boundaries are mostly very subtle and several seismic sections may have to be interpreted before any evidence is found to support the conclusions. The sequence boundaries were compared with established stratigraphy by identifying well ties and by projecting to outcrop data.

The processing of the digitised data by Petroseis^{TM} software facilitates the display of a variety of contoured, sectional and three dimensional data, and detailed isopach and structure contour maps, fence and isometric diagrams and cross-sections were used to illustrate thirteen mapped reflectors. This gave a better understanding of the geometry of the sedimentary packages and their subsurface configuration, and allowed a better interpretation of their genesis and palaeotectonic history.

The early subsidence history of the basin system was driven by thermal relaxation after a major episode of volcanic activity. Foreland loading in the Late Permian to Middle or early Late Triassic, with subsidence driven by thrust-plate loading, is the suggested mechanism for the later tectonic development of this region. Duplexing of the basement to the east is implied, with the thrusting being mainly west-directed. Maximum subsidence occurred adjacent to the thrust sheets where the load was greatest. It is estimated, from an interpretation of tectonic subsidence curves, that it took about 10 m.y. for the effects of the thrusting to be propagated 100 km to the west.

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APPENDICES
(MGN)

Appendix 1. List of maps available through BMR Sale Centre.

All maps are available as paper copies at a scale of 1:250 000. We refer to the maps as isopach maps or structure contour maps for convenience, but they have been compiled from seismic two-way travel time data in milliseconds and have not been converted to depth or thickness in metres.

Map No.	Description
1	Taroom Region shotpoint map (interpreted lines only)

Structure Contour Maps

2	S13 reflector - Westgrove Ironstone Member
3	S7 reflector - Base of Evergreen Formation
4	S22 reflector - Base of Precipice Sandstone
5	B10 reflector - Intra-Moolayember Formation
6	B46 reflector - Base of Moolayember Formation
7	B20 reflector - Intra-Clematis Group
8	B48 reflector - Base of Clematis Group
9	B44 reflector - Intra-Rewan Group
10	B33 reflector - Base of Rewan Group
11	B17 reflector - Base of Baralaba Coal Measures
12	B64 reflector - Base of Gyranda Formation
13	B26 reflector - Base of Flat Top Formation
14	B6 reflector - Base of Buffel Formation

Isopach Maps

15	S7 - S13	Base of Evergreen Formation to Westgrove Ironstone Member
16	S22 - S7	Base of Precipice Sandstone to base of Evergreen Formation
17	B10 - S22	Intra-Moolayember Formation to base of Precipice Sandstone
18	B46 - B10	Base of Moolayember Formation to intra-Moolayember Formation
19	B20 - B46	Intra-Clematis Group reflector to base of Moolayember Formation
20	B48 - B20	Base of Clematis Group to intra-Clematis Group reflector
21	B44 - B48	Intra-Rewan Group reflector to base of Clematis Group
22	B33 - B44	Base of Rewan Group to intra-Rewan Group reflector
23	B17 - B33	Base of Baralaba Coal Measures to base of Rewan Group
24	B64 - B17	Base of Gyranda Formation to base of Baralaba Coal Measures
25	B26 - B64	Base of Flat Top Formation to base of Gyranda Formation
26	B6 - B26	Base of Buffel Formation to base of Flat Top Formation
27	B33 - S22	Rewan & Clematis Groups, & Moolayember Formation (c. Triassic)
28	B6 - B33	Base of Buffel Formation to base of Rewan Group (c. Permian)
29	B6 - B17	Base of Buffel Formation to base of Baralaba Coal Measures

Appendix 2. Data from Petroseis™ available in digital format.

Digital data for the Taroom region includes shot point and horizon (reflector) data for all interpreted seismic sections or any combination of sections and horizon data. It can be exported in the following formats:

- Petroseis™ dump file, which can be imported into any Petroseis™ system.
- UKOOA or other fixed format ASCII dump file.

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