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EXECUTIVE SUMMARY

During the period December, 1994 to January, 1995, the AGSO research ship "Rig Seismic" was engaged in deep seismic profiling across the offshore parts of the Otway Basin south of Victoria and South Australia ("Rig Seismic" Survey No.137). The profiling was designed to enable structures within the deepest offshore parts of the basin and the underlying basement to be imaged.

The velocity information obtained from marine reflection profiling with maximum offsets of about 5 km will only be approximate in the deeper parts of the seismic sections and the interpretation of significant features may be compromised. Seismic data recorded at long offsets (wide-angle reflection/refraction data) provide this velocity information on the deeper parts of basin sequences and the underlying basement. To acquire this wide-angle seismic data during the 1994-95 "Rig Seismic" Otway Basin survey, seismic recorders were set up at thirteen sites in the South Australian and Victorian parts of the onshore basin. These seismic recorders ran continuously for periods up to 16 days and recorded the "Rig Seismic" airgun shots (at approximately 20 second intervals) at offset distances of over 200 km at some sites. The data will be used to interpret an improved velocity model for the deep basin and underlying crust.

This Record describes the onshore field operations connected with the wide-angle recording, and documents the data retrieval and digitising procedure. The shipborne operations have been described in a separate operations report (Cassim et al, 1995).

INTRODUCTION

During the period 1991-94 AGSO was a partner in the NGMA Otway Basin Project which examined the early rift features of the onshore Otway Basin in Victoria and South Australia. AGSO's partners in the NGMA project were the Geological Survey of Victoria (GSV), Mines and Energy, South Australia (MESA), and the Victorian Institute of Earth and Planetary Sciences (VIEPS). During the same period there was a substantial exploration effort by leaseholders in the basin, both onshore and offshore, which the NGMA project was designed to complement.

During the course of the NGMA project, there was considerable debate about appropriate tectonic models for the region and various significant features which had onshore and offshore expression were highlighted. AGSO onshore seismic reflection profiling highlighted the early rift segments along the northern margins of the basin with the Delamerian/Lachlan Orogen. The NGMA onshore mapping also highlighted the two-stage rift process in the Otway Basin (Williamson et al., 1990) during the separation of Australia and Antarctica, with the landward limits of the second stage rifting being along the Tartwaup - Timboon Fault system (Hill et al., 1995). The need to investigate the offshore areas of the basin to resolve oustanding issues became apparent.

Gravity data in the form of Geosat/Seasat images of the Southern Ocean, when integrated with onshore gravity data, have highlighted the region of extended and attenuated continental lithosphere which Finlayson et al (1993) termed the Otway-Sorell microplate. Again the relationship between the onshore and offshore parts of the basin was highlighted, with many previously unrecognised features becoming apparent. Exon et al. (1994), using side-scan sonar, have highlighted in spectacular fashion the importance of the Tasman Fracture System and its continuation along offshore west Tasmania as the Sorell Fault. Moore et al (1992) have emphasised the strike-slip nature of the offshore west Tasmanian margin. Cooper (1995), among others, has described the strong correlation of the Sorell Fault with onshore Otway Basin features (the Purrumbete-Sorell trend) using uplift histories determined from fission track analysis.

Add to the factors mentioned above the continuing interest of exploration companies, together with the State and Federal government departments, and there were compelling reasons for renewed marine geoscience work to look at the deepest Otway Basin sequences and the structures within basement rocks underlying the basin. The previous AGSO cruise in the Otway Basin during 1985 (Cruise 48) (Williamson et al., 1987) drew attention to the hydrocarbon potential of the offshore basin. However, during the last ten years there have been vast improvements in seismic data acquistion and processing technology which now enable greatly improved images of the deep basin and basement structures to be obtained. The current state-of-the-art technology enables much deeper features to be investigated in detail.

During 1994, O'Brien et al (1994) compiled a survey proposal for the offshore Otway Basin in co-operation with State surveys and industry. This survey (No.137) was conducted by the AGSO research vessel "Rig Seismic" during the period November, 1994 to January, 1995.

The 1994-95 Otway cruise provided an opportunity to tie results offshore with onshore areas of the basin using wide-angle seismic recording i.e. recording of seismic waves reflected and refracted from sub-surface horizons at onshore stations (Fig. 1). This style of recording has been used previously in a number of studies overseas and also during AGSO's projects in the Gippsland Basin in southeastern Australia (Collins et al., 1992) and in the Browse Basin in northwestern Australia (Symonds et al., 1994). The objective of the Otway Basin wide-angle seismic recording was to

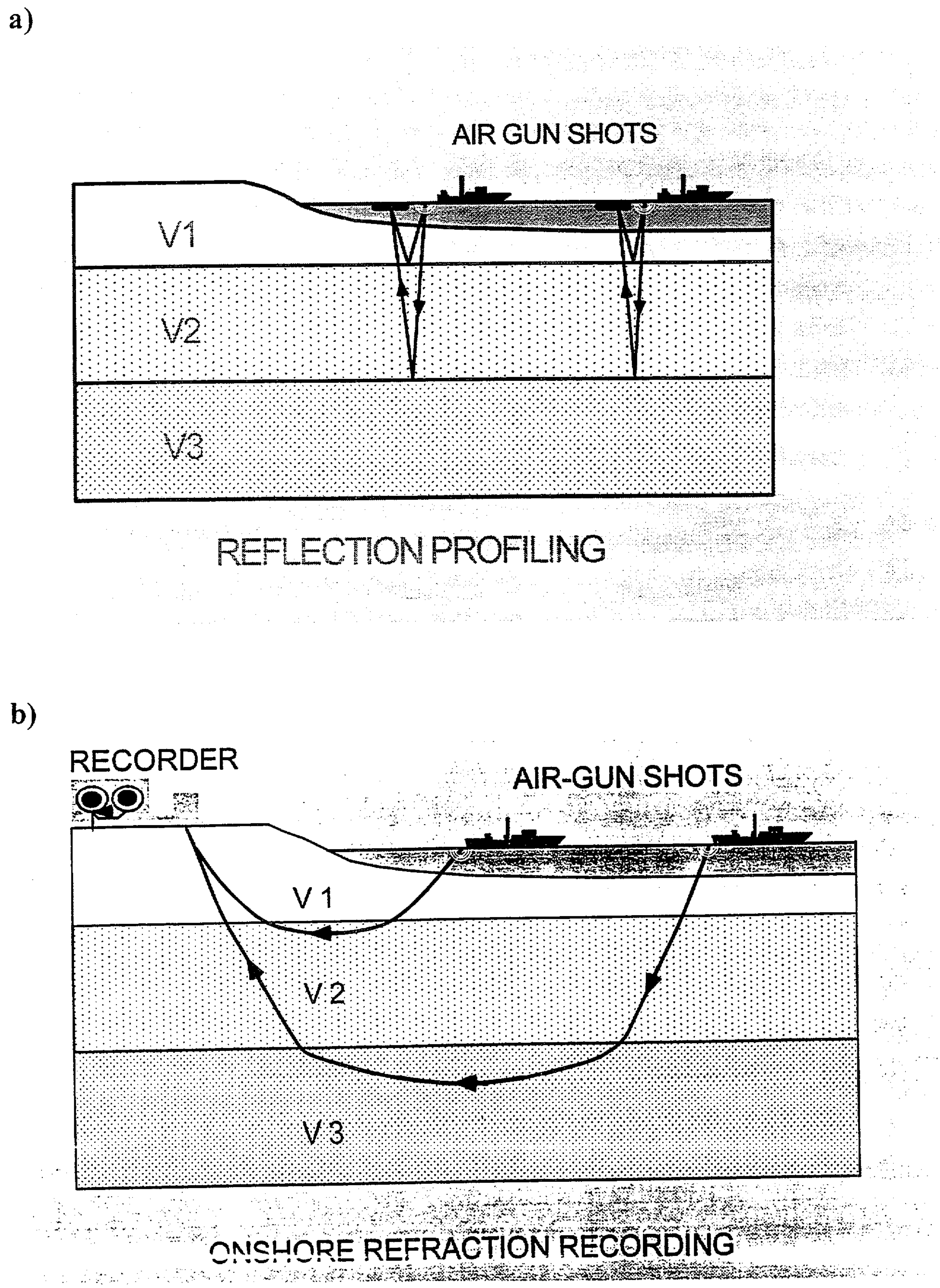

Fig. 1 Simplified diagram of a) near-vertical seismic profiling, and b) wide-angle (offshore - onshore) seismic profiling.

provide an improved velocity model within the deeper parts of basin sequences and also within the attenuated basement rocks under the continental shelf and slope. This information will be tied to the reflection profiling data acquired during the 1994-95 AGSO cruise and provide greater confidence in the interpretation of deep basin and basement features.

REGIONAL GEOLOGY

The regional geology of the Otway basin has been summarised in a number of papers (Megalla, 1986; Kopsen & Scholefield, 1990; Williamson et al., 1987, 1990; Sprigg, 1986; Laing et al., 1989; Hill & Durrand, 1993; Pettifer et al., 1991; Yu, 1988). The summary presented here has been adapted and simplified largely from the work of Morton et al. (1994), Perincek et al. (1994), Hill et al. (1994) and Finlayson et al. (1995 in press).

Structural elements

A simplified map of the Early Cretaceous syn-rift faults and Late Cretaceous breakup faults for the onshore Otway Basin has been compiled from mapping by NGMA partners (e.g. Perincek et al, 1994; Hill et al., 1994; Finlayson et al., 1995 in press). Three major trends are discerned: 1) E-W (e.g. Robe Trough, Morenda Trough, Elingamite Graben), 2) NW-SE (e.g. Penola Trough, Ardonachie Trough), and 3) NE-SW (e.g. Colac Trough, Yaloak Graben). As described below, many of the major faults are associated with rifting and the formation of Early Cretaceous half-graben. These faults are seen to play an important role in the development of structures throughout the history of the basin. Seaward of the Early Cretaceous rifts are the Late Cretaceous Tartwaup and Timboon fault systems, interpreted as headwall faults for the extensional basin formed during the separation of Australia from Antarctica (Finlayson et al., 1995 in press). South of this headwall fault system, Early Cretaceous horizons are deep and difficult to map.

From various studies around the world, there is now a considerable body of information on the possible influence of pre-existing geology on the geometry of early rifting within a continental setting. In Africa, for instance, the Cainozoic rift system is influenced largely by older cratonic blocks separated by pre-existing zones of crustal weakness inherited from earlier pan-African orogeny (Binks and Fairhead, 1992; Guiraud & Maurin, 1992). In eastern Africa, Rosendahl et al. (1992) were "impressed with the role that Proterozoic dislocation zones seem to play in regard to the architectures of the Western Branch (East African) rifts". Scott (1994), when studying some Australian passive margins, concludes that " rift zone scale geometry is influenced by pre-existing deep-seated, large-scale crustal structures and lateral heterogeneities in the lithosphere". In southeastern Australia the structures within the Delamerian and Lachlan Orogens are likely to have influenced the early rift segments within the Otway Basin.

Basin stratigraphy

As part of the NGMA Otway Basin Project, Morton et al. (1994) have described the stratigraphy of the whole Otway Basin in terms which seek to reconcile some of the diverse descriptions and views that have been expressed by a number of previous authors working in South Australian and Victorian parts of the basin. The stratigraphic nomenclature is shown in Figure 2. This nomenclature is favoured here.

Palaeozoic Basement

Palaeozoic metasediments and igneous rocks underlie the Otway Basin sequences. These are intersected in a number of wells on basement highs and along the northern margins of the Otway Basin including Ballangeich-1, Ferguson Hill-1, Garvoc-1, Stoneyford-1, Tirrengowa-1, Cressy-1, Mortlake-1, Hatherleigh-1, Kalangadoo-1, Lake Eliza-1, Robertson-1&2, Sawpit-1, Lucindale-1, and Beachport East-1. The well completion data from these wells strongly suggest that the Palaeozoic metasediments and granites of the Lachlan Orogen cropping out to the north of the basin form basement to the Otway Basin sequences.

Casterton Formation and Crayfish Group

The Late Jurassic (Kimmeridgian-Oxfordian to Tithonian) Casterton Formation has been described by Morton et al. (1994) as an essentially pre-rift or earliest synrift sequence comprising interbedded carbonaceous shale, minor feldspathic sandstone and siltstone and basaltic volcanics. Details of the formation geology are poorly known. An unconformity separates the formation from Crayfish Group sequences. Casterton Formation sequences are identified in a number of wells including Ballangeich-1, Moyne Falls-1, Hawkesdale-1, Woolsthorpe-1, Pretty Hill-1, Bus Swamp-1, Casterton-1, and Sawpit-1.

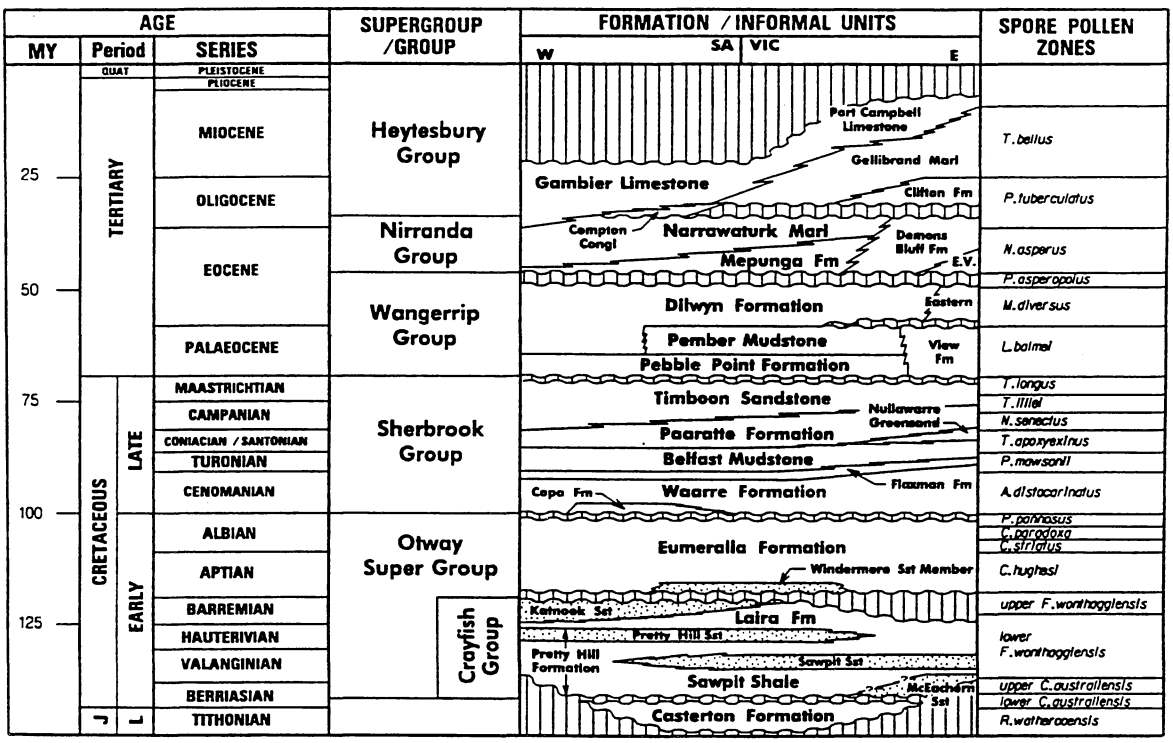

Fig. 2 Stratigraphy of the Otway Basin region (from Lovibond et al., 1995).

The overlying Early Cretaceous Crayfish Group (Berriasian to Barremian) consists of early syn-rift, non-marine, graben fill sequences that are separated from the overlying Eumeralla Formation by an unconformity e.g. Morton et al. (1994). A strong angular unconformity is evident in the western Otway Basin but is gradational in the east and not as easily recognised. The Crayfish Group comprises the Pretty Hill Formation (sand and shale), and, in the western basin, the overlying Laira Formation and Katnook Sandstone.

As might be expected in syn-rift sequences (e.g. Prosser, 1993), the Crayfish Group exhibit overall wedge-shaped geometries in a number of rift segments throughout the basin. In the shallower parts of the basin the Crayfish Group is intersected in wells such as Ballangeich-1, Garvoc-1, Ross Creek-1, Stoneyford-1, Tirrengowa-1, Purrumbete North-11, and Warracburunah-2, Moyne Falls-1, Hawkesdale-1, Pretty Hill-1, Tullich-1, Bus Swamp-1, Penola-1, Kalangadoo -1, Crayfish-A1, and Trumpet-1.

Eumeralla Formation

The Early Cretaceous Eumeralla sequence (Aptian to Albian) is a thick sequence, predominantly shaley in the west but sandier in the east. Unlike the Crayfish Group which mostly occurs in half graben separated by basement highs, the Eumeralla Formation is seen as a basin-wide blanketing sequence, although sequence thickening in the east suggests continued lithospheric extension in that part of the basin in the late Early Cretaceous. The Eumeralla Formation is identified in numerous wells below the top-Albian unconformity. The formation thickness can vary enormously across the basin, ranging from 156 m in Warracburunah-2, 673 m in Ballangeich-1 and 696 m in Stoneford-1 to 2581 m in Ross Creek-1, 2743 m in Ferguson Hill-1, and more than 2302 m in Olangolah-1. Wells in the central and western part of the basin which intersected the Eumeralla Formation include Eumeralla-1, North Eumeralla-1, Tullich-1, Penola-1, Banyula-1, Beachport-1, Trumpet-1, Crayfish-A1, Bus Swamp-1,and Geltwood Beach-1.

Sherbrook Group

The overlying Late Cretaceous and Tertiary sequences are of considerable importance as targets in the exploration for hydrocarbons, particularly in the southern onshore and offshore areas. The Late Cretaceous Sherbrook Group (Cenomanian to Maastrichtian) comprises very large scale delta sequences, mostly conformable but locally unconformable (Morton et al., 1994) overlying the Eumeralla Formation. The large-scale flooding surfaces tend to contrast the Sherbrook Group sequences on seismic sections from the underlying Eumeralla Formation and this is used to map the top Eumeralla Formation horizon. The sequences of the Sherbrook Group have been described in detail by Mehin & Link (1994) but offshore mapping during recent phases of exploration will probably lead to future revision of Lower Sherbrook Group nomenclature.

In the eastern Otway Basin area the significant thicknesses of Sherbrook sequences are confined to the Port Campbell Embayment. Many exploration wells intersect the Sherbrook Group sequences in the onshore part of this embayment including Elingamite-1, Ross Creek-1, Bartons Corner-1, Sherbrook-1, Curdie-1, Flaxmans-1, and Port Campbell-2. Seismic data suggests that the sequence becomes deeper in the Sherbrook Trough in the southeast Port Campbell Embayment. In the western and central parts of the basin there are significant thicknesses of Sherbrook Group seaward of the Tartwaup Fault Zone. Wells intersecting the group include Kalangadoo-1, Copa-1, Caroline-1, and Burrungule-1.

Morton et al. (1994) describe the basal non-marine Waarre Sandstone, overlain by interbedded sand/shale of the Flaxman Formation, the Belfast Mudstone (pyritic marine prodelta shale), the Paaratte Formation (regressive paralic deltaic), and the non-marine Timboon Sandstone. Recent reviews of exploration targets in the eastern Otway Basin have identified a unit loosely equivalent to the Waarre Sandstone and informally termed the Shipwreck Group (O'Callaghan, 1993) which has mappable upper and lower sequence boundaries coincident with periods of tectonism and erosion on the eastern basin margin.

Tertiary Sequences

In the Otway Basin the Tertiary sequences comprise the Wangerrip Group (Palaeocene to Mid-Eocene), the Nirranda Group (Mid-Eocene to Oligocene), and the Heytesbury Group (Late Oligocene to Mid-Miocene). These sequences blanket most of the basin, with noteable exceptions across the Otway Ranges and Merino High. The sequences have been described recently by Morton et al. (1994) and the detail is not repeated here; the groups are formed from a series of trangressive-

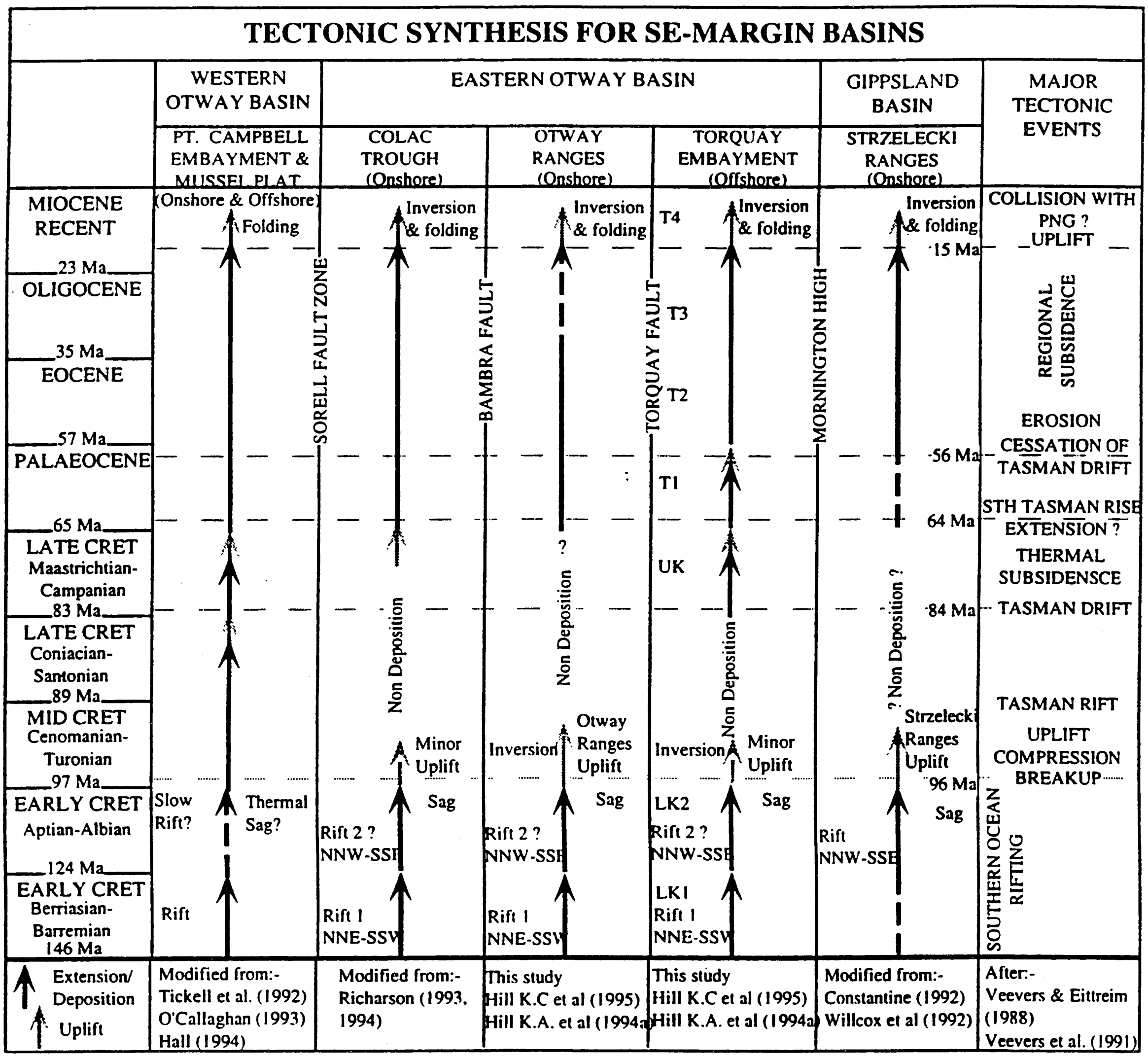

Fig.3 - Tectonic evolution of the Otway Basin region based on seismic and thermochronological data (from Cooper, 1995)

regressive units that comprise the Tertiary sequence in the Otway Basin.

Representative sections of Tertiary sequences can be seen in wells across the eastern Otway Basin including Ballangeich-1, Bartons Corner-1, Curdie-1, Ellingamite-1, Ferguson Hill-1, Flaxmans-1, Garvoc-1, Port Campbell-1, Ross Creek-1, Stoneyford-1, and Warracburunah-2.

Pre-drift Basin Development

Figure 3 shows a tectonic synthesis chart of the Otway Basin (from Cooper, 1995). In the basins of the Bass Strait and Otway region, the orientations of early rift segments have been described by Perincek et al. (1994), Hill et al. (1994), and others. Perincek et al. (1994) have interpreted the fault timing across the onshore basin and it is evident that many of the major structures of the early rifting events are reactivated during subsequent extensional and compressional episodes throughout the basin's history.

As discussed earlier, Morton et al. (1994) describe the Late Jurassic (Kimmeridgian-Oxfordian to Tithonian) Casterton Formation as a pre-rift or earliest synrift sequence comprising interbedded carbonaceous shale, minor feldspathic sandstone and siltstone and basaltic volcanics. Major extension during the Early Cretaceous (Berriasian to Barremian) led to the deposition of the Crayfish Group sequences. In the Colac Trough there is strong divergence of the sequence internal reflectors towards a single E-W striking, north-dipping extensional fault (the Gellibrand Fault) (Richardson, 1993). In the western Otway Basin, the rifting axis moved south from the major Robe-Penola Troughs to south of the Tartwaup hingeline after the Barremian.

Overlying the early Aptian unconformity is the widely distributed Eumeralla Formation indicating regional subsidence of the basin. In places there is a large amount of immature volcaniclastic sandstone. Constantine (1992) indicates the sediments were probably deposited in a wide flood plain over which flowed diverse river systems. Felton (pers. comm.) indicates that the broad extent of lithofacies implies a high degree of connection between depositional systems in the Otway Basin by the early Aptian, with the possibility of a rift-related volcanic source offshore from the present coast. Others (e.g. Hill et al., 1995) have favoured a sediment source in the arc-related volcanism much farther east at margin of Gondwana.

Otway Super-Group sedimentation was terminated by Mid-Cretaceous uplift and compression in the eastern Otway Basin. This resulted in the formation of the Otway Ranges and Cape Otway-King Island Highs. These structural highs partitioned the basin into two distinct sedimentary provinces (Williamson et al., 1987). The area, including and immediately east of the Cape Otway-King Island High, remained high during the Late Cretaceous with no evidence of deposition (note: farther east there is evidence of Late Cretaceous extension in the Durroon and Gippsland Basins). In contrast, the areas west of the high, including the Tyrendarra and Port Campbell Embayments, the Voluta Trough and the offshore Mussell Platform, subsided and the Sherbrook Group (Cenomanian to Maastrichtian) sequences were deposited. Onshore, the Stoneyford High separating the Colac Trough from the Port Campbell Embayment, is probably associated with the fundamental structures separating the eastern and western parts of the Otway Basin (Cooper's (1995) Sorell-Purrumbete trend).

Post-Albian Basin Development

The post-Albian history in the western Otway Basin is essentially associated with continental breakup which ultimately separated Australia from Antarctica. Hill et al. (1994) have reviewed the information on pre-drift tectonics in the Otway Basin region and their preferred timing of ca 95 Ma for breakup follows the work of Cande & Mutter (1982) and subsequent work of Veevers (1986). Cooper et al. (1993) and Duddy (1994), using thermochronolgy, have emphasised the major nature of a regional rapid cooling event at 95±5 Ma which included the uplift and erosion of the Otway Ranges. This time is interpreted as the onset of slow drift between Australia and Antarctica by Veevers (1986, 1990) at a time when major events were also occurring in the Indian Ocean and the Tasman Sea (Veevers et al., 1991).

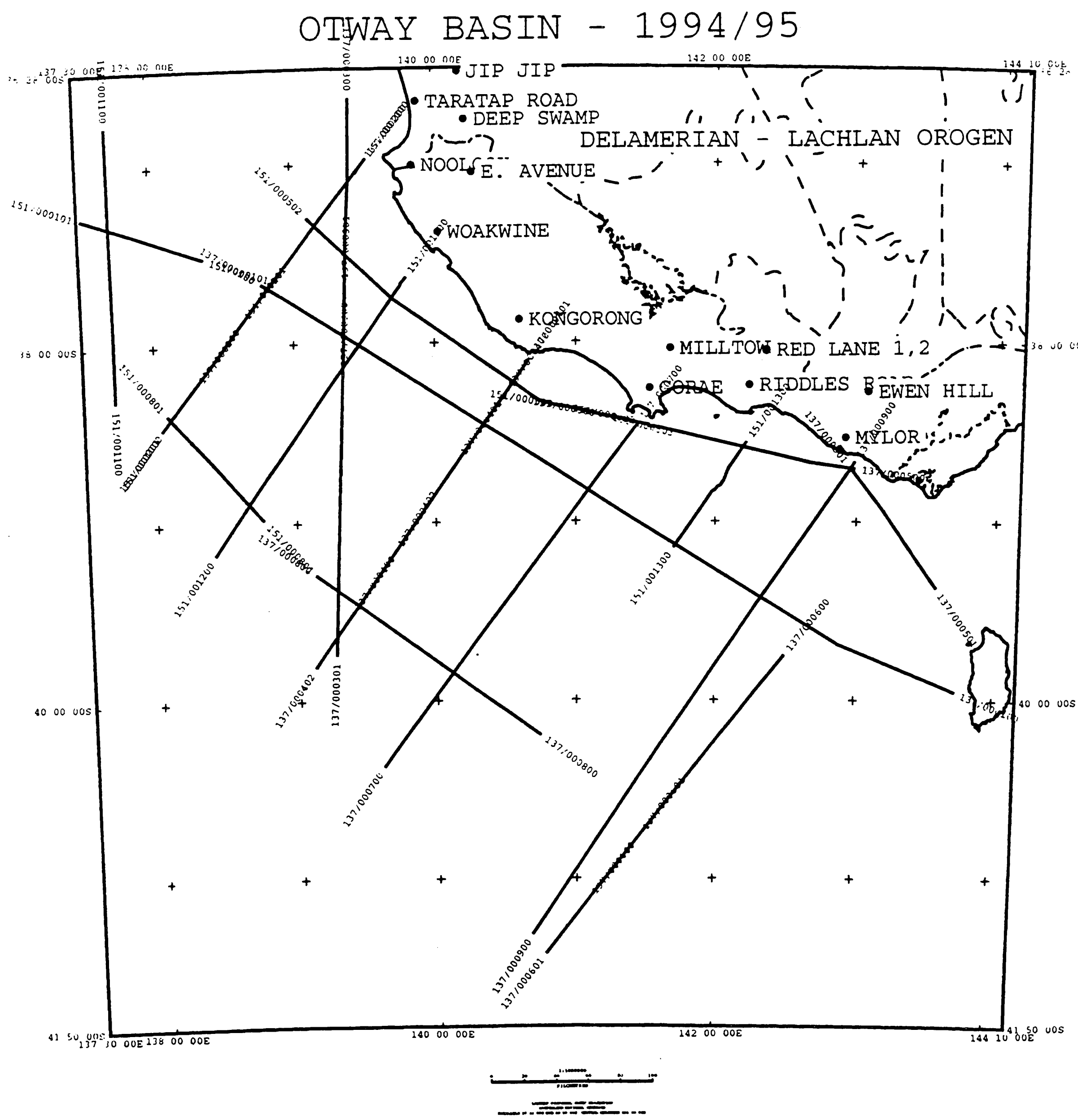

Fig. 4 - Location of "Rig Seismic" ship tracks during the 1994-95 Otway Basin Survey No.137 and the sites used for onshore recording of the airgun seismic source.

In the Southern Ocean, off southern Australia, the gravity information compiled from Geosat and Seasat data provide outstanding images of the pattern of post-Albian sea floor geology for the offshore Otway Basin and the adjacent oceanic crust (Finlayson et al., 1993). A combined image of onshore Bouguer gravity and offshore satellite data shows the transitional location of the Otway Basin on Australia's southern margin. To the west, the separation between Australia and Antarctica occurred relatively close to continental Australia; to the east, rifting failed to develop through the Bass Strait, instead being offset to the south of Tasmania.

The triangular region of extended continental lithosphere to the northeast of the prominent Geosat gravity lineament between South Australia (Cape Jaffa) and southern Tasmania (South West Cape) has been termed the Otway-Sorell microplate by Finlayson et al. (1993). The eastern boundary of the microplate is taken to be the sinistral Tasman Fracture System extending along western Tasmania and the South Tasman Rise (Exon et al., 1994), and the northern boundary is taken to be the failed rift system along the northern limits of the Otway Basin (Finlayson et al., 1993). The essential crustal architecture of this microplate was formed in the period between the initiation of earliest Otway rifting (115-120 Ma; Williamson et al., 1990) and the formation of the oldest oceanic lithosphere adjacent to the microplate (95-96 Ma; Veevers et al., 1991). The microplate continued to be attenuated and modified by Late Cretaceous and Tertiary events. The Southern Ocean seaway probably did not develop fully until Antarctica cleared southern Tasmania in the Eocene (about 40 Ma) (Exon et al., 1994).

The region between the Spencer and Tasman Fracture Systems, the Otway-Sorell Microplate, is a transitional region between the margin to the west where rifting of the Precambrian craton occurred, and the margin to the east which has been influenced by Palaeozoic structures associated with the eastern Gondwana plate margin.

After the major uplift at about 95 Ma, there have been late compressional/inversion events affecting the Otway Basin sequences. K. C. Hill et al. (1995) have descibed Miocene to Recent inversion of earlier fault systems. They describe Neogene inversion of Early Cretaceous extensional faults in the Colac Trough area and offshore in the Torquay Sub-Basin they descibe three southeast-verging monoclinal structures at the top Oligocene level. The offshore Nerita-1 well is drilled on an anticlinal structure interpreted to have formed by Pliocene to Recent inversion. The present structure of the Otway Ranges is interpreted to be due to Miocene-Pliocene inversion of Cretaceous and ?Palaeogene extensional faults at the time of the collision of the Australian craton with island-arc terrains to the north in the Indonesian - New Guinea region.

Perincek et al. (1994) descibe Miocene to Recent faulting as being characterised by a new generation of normal faulting and reactivation of major Cretaceous rift bounding faults. They interpret some structures consistent with right-lateral stike-slip movement roughly oriented NW-SE during post-Oligocene times.

WIDE-ANGLE SEISMIC RECORDING - SURVEY DESIGN

The wide-angle seismic recording in the Otway Basin focussed on two regions. These were 1) the Port Campbell Embayment and the adjacent offshore Mussel Platform, and 2) the Beachport Terrace offshore area in the western part of the basin in South Australia. Figure 4 shows the location of ship tracks and onshore recording stations. Six PI seismic tape recorders (Finlayson & Collins, 1980) were used during the survey. These recorders were capable of recording for about 16 days with a 7200 foot, 14 inch reel of ½ inch tape (the maximum length available) on each recorder.

During December 1994, seismic recorders were deployed in three pairs at sites in the Port Campbell Embayment. Each pair of stations was located along the shoreward extension of proposed ship tracks running approximately at right angles to the coast to the continental slope limits. One station was located about 10 km from the shoreline and the other was deployed about 40 km from the shoreline. Experience in similar work in the Gippsland Basin has shown that ocean-generated seismic noise can swamp the ship-sourced seismic signals and saturate recording amplifiers if stations are too close to the coastline. Hence the cautious approach to deploying stations close to the ocean. Stations were also located to record from ship tracks running parallel to the shore across the Mussel Platform.

During January, 1995, seismic recorders were deployed at seven sites in the western Otway Basin and the adjacent Padthaway High. The target areas were the Beachport Terrace extending offshore from the St. Clair and Robe Troughs. Recorders were moved during the shipborne operations so that recordings could be obtained from specific ship tracks. As in the Port Campbell Embayment, sites were chosen away from the shoreline. Details of the deployments are set out in the following chapter and in Appendix 1. During this time the "Rig Seismic" completed traverses parallel to the coast extending east to the Mussel Platform. Consequently four sites in the Port Campbell Embayment were re-occupied at this time (see details below) in an attempt to record data at both ends of the ship track simultaneously.

ONSHORE RECORDING OPERATIONS

Recording operations in Victoria during December, 1994, were conducted by D. M. Finlayson and E. Chudyk. Equipment was deployed at six sites at the beginning of the cruise, left to operate unattended, and picked up at the end of the first phase of the cruise shortly before Christmas. Operations during January, 1995, were conducted by E. Chudyk who was in the field for the duration of recording and who relocated recorders as required..

Recording equipment

The recording of seismic data was made on slow-speed Precision Instrument (PI) analogue tape recording systems which have been described by Finlayson & Collins (1980). Six recorders were used during the survey. Each system used a Willmore Mk2 seismometer partially buried in surface soils. Seismic signals to each recorder were amplified and filtered through an AGSO TAM5 amplifier at two gain levels, frequency modulated and recorded on two tracks of a (half-inch) PI tape recorder. A temperature-compensated crystal oscillator (TCXO) clock signal, complete with time code, was also recorded on a third channel. A universal time standard code derived from the Omega VLF time signal transmitter at Yarram, Victoria was also recorded on tape. This Omega code was used to set the internal clock and also recorded on a fourth PI channel as a modulated signal. During January, 1995, the Omega transmitter was off the air intermittently for servicing.

Details of the equipment settings at each of the recording sites is contained in tables associated with Appendix 1.

Recording tape

During pre-survey overhaul and testing of equipment in Canberra, considerable difficulty was experience with poor quality tape provided by a previously reliable supplier. It was demonstrated that the tape performance was unreliable and it was concluded that there was a fault in the oxide coating. This was the same batch of tape which resulted in poor recordings being made on the PI recorders during the AGSO 1994 Mt. Isa survey. Never take a new batch of tapes into the field without testing them beforehand.

Recorder timing

Timing is of paramount importance for seismic recoding. The "Rig Seismic" airgum shots are timed using a GPS clock to an accuracy of 0.01 seconds. The recorder timing must also be linked to an absolute time standard. This was done using the Omega VLF time signal tranmitted from Yarram, Victoria.

The AGSO-designed Omega VLF time signal receivers fitted to the PI recorders receive the Omega VLF signal and convert it to a series of amplitude-modulated second time pips with a longer tone every ten seconds (Liu et al., 1987; Straatmans & Smith, 1988). The time signal receiver does not emit a minute tone different from the ten-second tone. This decoding/encoding is necessary because the Omega time standard,originally set to UTC (Universal Co-ordinated Time) in 1972, has not been updated over the years for leap seconds. The difference in the case of eastern Australia was 16.022 seconds during the 1994-95 survey. However, it does mean that the operator has to rely on his/her watch, set every day by listening to a Telecom time check to get Victorian Summer Time, to know when to reset the seismic recorder clocks.

The timing of the ten-second tones put out by the AGSO Omega receiver can be set to trigger at any particular second using a series of internal switches. It is claimed by some that it is inconvenient to record the ten-second tone on top of another minute marker from another source e.g. internal clock, VNG or WWV. In the case of the recorders used during the Otway Basin survey in December, 1994, in three recorders the ten-second tone was 5 seconds before the true minute (Victorian Summer Time). In the other three recorders the minute tone was 8 seconds before the true minute (Victorian Summer Time). These miscellaneous settings were a legacy of the previous use of the recorders during 1994 in the Mt. Isa region and are very annoying an confusing for some field operators. The settings are noted in Appendix 1.

By agreement among field operators, the proceedure during recorder setup was to, 1) each day set a wrist-watch to the Telecom time to better than 0.1 second, 2) listen to Omega ten-second tones in each recorder and determine the difference from the wrist-watch minute (note it on the log sheet), and 3) reset the recorder clock on the first ten-second tone after the wrist-watch minute. After advancing or retarding the clock to reduce the error to about zero milliseconds, the recorder clock and the Omega ten-second should coincide when played back onto a paper chart recorder.

During January, 1995, three recorders had the Omega switches changed so that the difference between the Omega ten-second tone and Victorian Summer Time was zero (see details in Appendix 1). In future it is recommended that this zero time difference be set on all recorders.

Recording sites

Fourteen onshore seismic recording sites were occupied during the 1994-95 Otway cruise of the "Rig Seismic". Six of these sites in Victoria were occupied during December, 1994. The remaining sites in both South Australia and Victoria were occupied during January, 1995. Some of the

December, 1994, sites were re-occupied during January, 1995, to tie datasets together.

Sites were chosen to be associated with specific ship tracks proposed during the planning phase of the cruise. Because of various operational difficulties encountered by "Rig Seismic", some proposed lines were not profiled. The ship tracks shown in Figure 3 represent the ship tracks finally acquired, with the track numbering initially specified during the cruise.

The details of the recording site locations, periods of recording, and instrumentation at each site are contained in tables attached to Appendix 1. Sites were often chosen to be in close proximity to exploration wells or onshore seismic lines where information on the sedimentary sequence was readily available to assist the interpretation of the current seismic data, e.g. sites adjacent to Gorae-1 and Mylor-1 wells and the Ewen Hill site on AGSO 1992 Seismic Line 2 near Lake Bullen Merri. Seismometer positions were determined by taken 20-30 global positioning satellite (GPS) readings at each site. Written logs were kept on the deployment and instrument settings on each seismic recording instrument while they were "active".

"RIG SEISMIC" OPERATIONS

Summary of cruise operations

The "Rig Seismic" survey proposals for Survey No.137 are contained in AGSO Record 1994/61 (O'Brien et al., 1994). Figure 5 is a map of the proposed ship tracks which was used to determine the locations of seismic stations. The ship tracks actually profiled by the "Rig Seismic" are shown in Figure 4.

The "Rig Seismic" Survey No.137 was conducted in two parts with a break over the Christmas/New Year holiday period. The first part of the survey was conducted in the period 26 November to 21 December, 1994. The second part was conducted in the period 10-23 January, 1995. Profiling was not conducted along all lines in the survey proposal. Poor weather and a medical emergency conspired to reduce the overall amount of shiptime available for profiling.

Some details of the shipborne operations (Cassim et al, 1995) are contained in Appendix 2. It should be noted that the cruise and track numbers quoted in this Record are those assigned at the time of the cruise. At the time of acquisition two survey numbers were assigned to the cruise, No.137 for the November-December, 1994, phase and No.151 to the January, 1995, phase. Survey No.137 was later allocated to the combined phases of the Otway cruise.

Seismic profiling lines and database

The positions and times of all shots on all lines are available as separate log files from the data acquired during seismic profiling. Position data for the airguns is required routinely for all industry standard data to enable the reflection profiling data to be stacked and processed. The times of shots are obtained from the GPS clocks used in conjunction with the acquisition of navigation data. These times must be logged to 0.01 sec accuracy for use with the shore-based recordings. Checks must be made prior to the survey that this is, in fact, being done.

The log files of shot positions and times have to be combined to produce a single input file for each "Rig Seismic" line required for automatic digitizing of the onshore seismic records. There may be many thousands of shots on each line (discussed later in the following chapter on data retrieval).

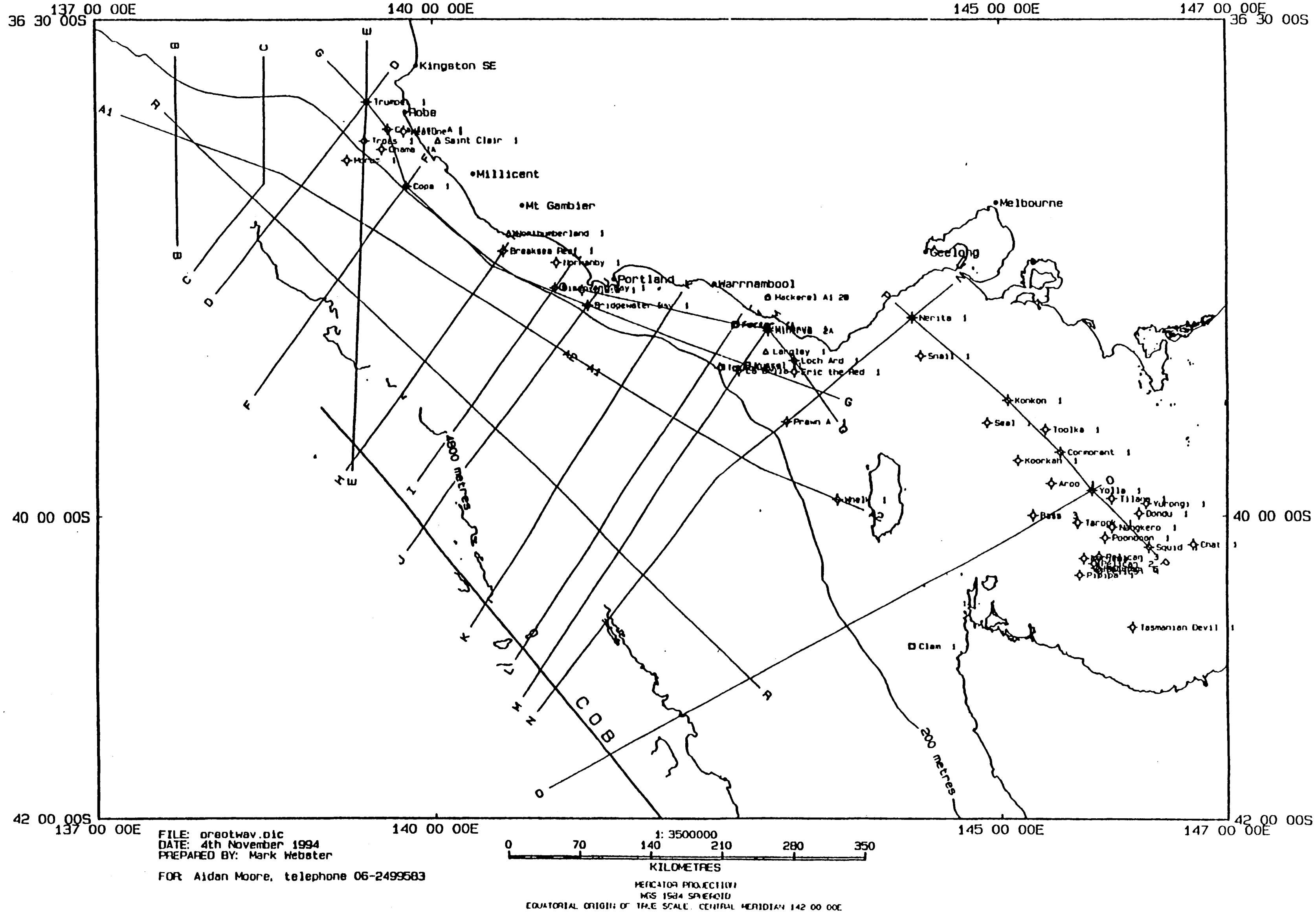

Fig. 5 - Map of proposed seismic tracks for Survey No.137. COB = continent-ocean boundary.

SEISMIC DATA RETRIEVAL

The methods and systems used for data retrieval and processing have been decribed by Collins et al. (1992) and will not be repeated here. However, there are important updates to the computer programs and data management systems used that make a desciption of these necessary.

Examples of the files and formats used in the data retrieval, processing and record section production are contained in Appendix 3.

Digitising of analogue tape records

The processing stream for the digitising of field tapes is shown diagramatically in Figure 6 and described below.

The analogue 1/2 inch field tapes were digitised by a PDP11 computer linked to a Thermionics tape playback system. The computer consisted of two hard disk and two floppy disk drives and operated under the Digital RSX-11M Plus operating system. The software included a Fortran77 compiler and Calcomp plotting library. The analogue-to-digital conversion was performed by Data Translation hardware and library routines.

The Otway 1994/95 refraction data was digitised using TEST97, an improved Fortran program from previous surveys. The program now allows the digitising process to run continuously for long periods of time without operator intervention. The digitising is dependent on the quality of the clock signal recorded on the field tape. Long periods of bad signal (up to 11 minutes in duration; e.g. 35 shots x 20 sec.) are accounted for by the program, so that the playback can remain uninterrupted until the specified number of samples has been acquired. Previous routines used in digitising marine refraction data did not handle poor sections of the tape as well as the current program, making the process more time consuming (the tape had to be frequently stopped and restarted).

TEST97 requires an input file with fixed parameters for each digitising session (by convention it was called INFILE.DAT), and a shot file containing shot numbers, distances and times for a particular traverse (standard file name format being AAABB.DAT where AAA was the numeric three digit line number and BB the alphabetical station name (usually first two letters). Shown below is an example of one of the input files used during processing of Otway 1994/95 refraction data.

INFILE.DAT

091294 .... *Survey Date (start of recording)*
OTWAY94 .... *Survey Description*
84 .... *Recorder Gain*
1.0 .... *Shot Weight (1.0 for marine data)*
2 .... *Channel Digitised (1=Low, 2=High)*
4 .... *Tape Playback Speed (4 times true speed for PI tapes)*
4 .... *Digitising Sample Interval (4ms)(i.e. seismic signal sample interval = 4x4 = 16 ms)*
1 .... *Station Number (1=Milltown)*
11 .... *Time Interval to Digitise Each Shot (11sec long traces)*
4 .... *Number of Seconds to Start Digitising Before Expected Arrival (4sec)*
37000 .... *Number of Program TEST97 Cycles Before Miss Recorded (for shots fired every 20sec)*
500MI.DAT .... *Name of Shot File Containing Shot Numbers, Distances and Times*
(Line 500 from Milltown in this case)

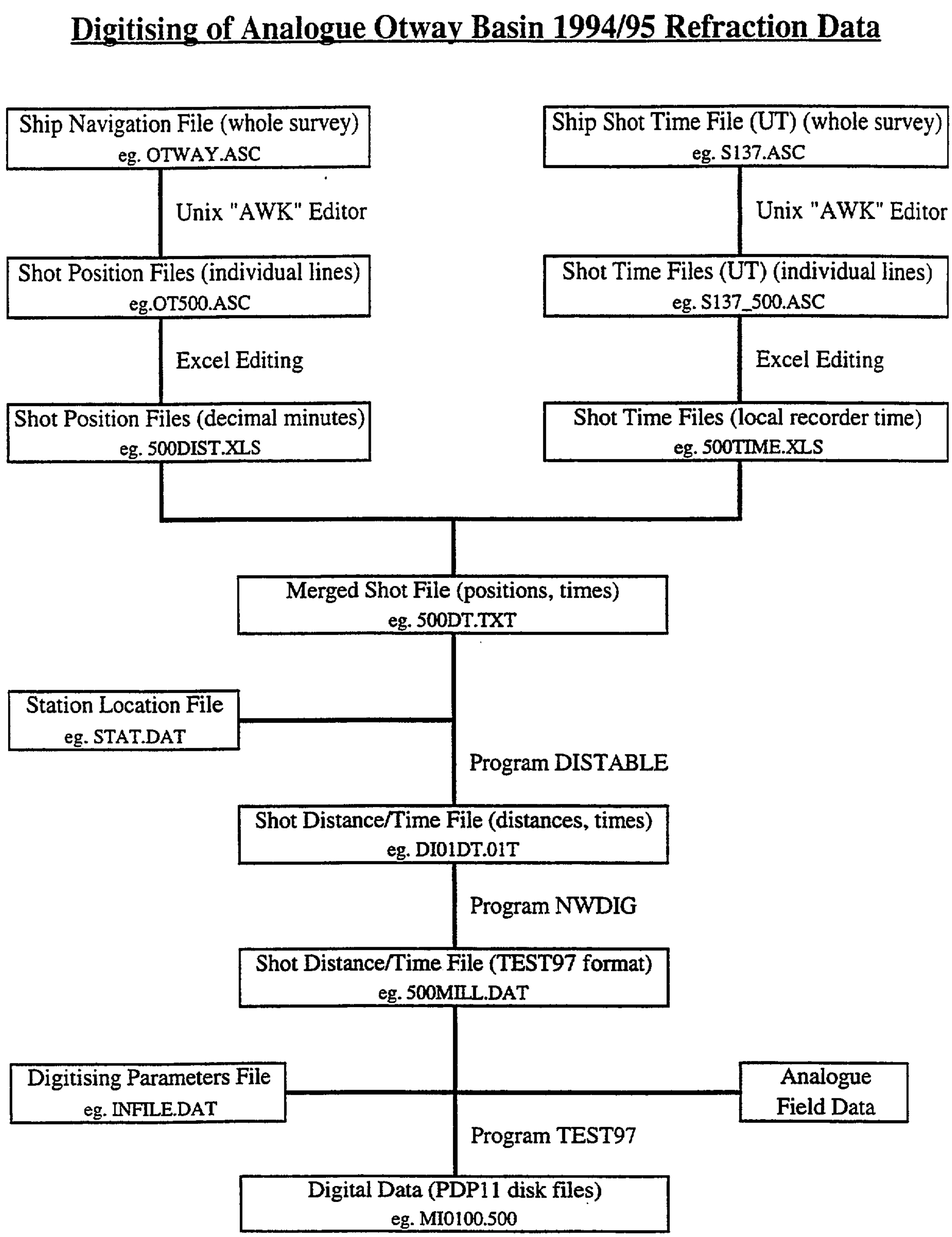

Fig. 6 - Processing stream for the digitising of field tapes.

At each run of TEST97, the following parameters were specified:

- the total number of shots to be digitised
  (usually the total number of shots on a given traverse, eg. 3304 for Line 500),

- maximum number of consecutive misses to be allowed by the program
  (10 used during this survey),

- directory and name of the output file containing digitised data

The following format has to be observed: AAA:[BBBBBB]CCDDDD.EEE, where

- AAA:[BBBBBB] specifies the path name of the PDP11 directory; AAA is one of the PDP11 hard disks (DU0: or DU1:) (3 characters), and BBBBBB the directory name (6 characters)
  (in the case of this survey, data was being downloaded into DU1:[OTWAY1] directory),

- CCDDDD.EEE specifies the file name; CC is an alphabetical prefix (usually the first two letters of the station name), DDDD is the numeric four-digit shot number, and EEE is the three digit extension (the traverse number))
  (eg. MI0100.500 for the file containing data from line 500 at Milltown, where the first shot number is 100).

TEST97 calculated the digitising start times using the following two equations:

(I) Digitising Time = Distance/6.0 - No. of Seconds Before Expected Arrival
(for crustal waves, Distance <= 120km), and

(II) Digitising Time = (Distance/8.0 + 5.0) - No. of Seconds Before Expected Arrival
(for mantle waves, Distance > 120km).

In the case of Otway 1994/95 refraction survey, the majority of the recording sites were located on thick sediments (as opposed to basement, eg. Browse Basin 1993 refraction survey). This fact, coupled with significant water depth encountered on some of the traverses, caused an additional delay in the expected arrival times. A constant factor of 4 seconds was added to (I) and (II) in TEST97, to make the start-of-digitising times correct.

During processing of Otway 1994/95 refraction data it was often possible to digitise entire lines in one single file. Because of the space confinements on the PDP11, the DU1:[OTWAY1] directory had to be emptied periodically to make room for new acquisitions. Prior to deletion, the data was copied to 9 track tape on the Cipher tape drive and archived in a compressed form using the RSX-11M Plus BRU tape backup utility.

Digital File Management

The processing stream for the handling of digitised data is shown in Figure 7 and described below.

Processing of Digitised Otway Basin 1994/95 Refraction Data

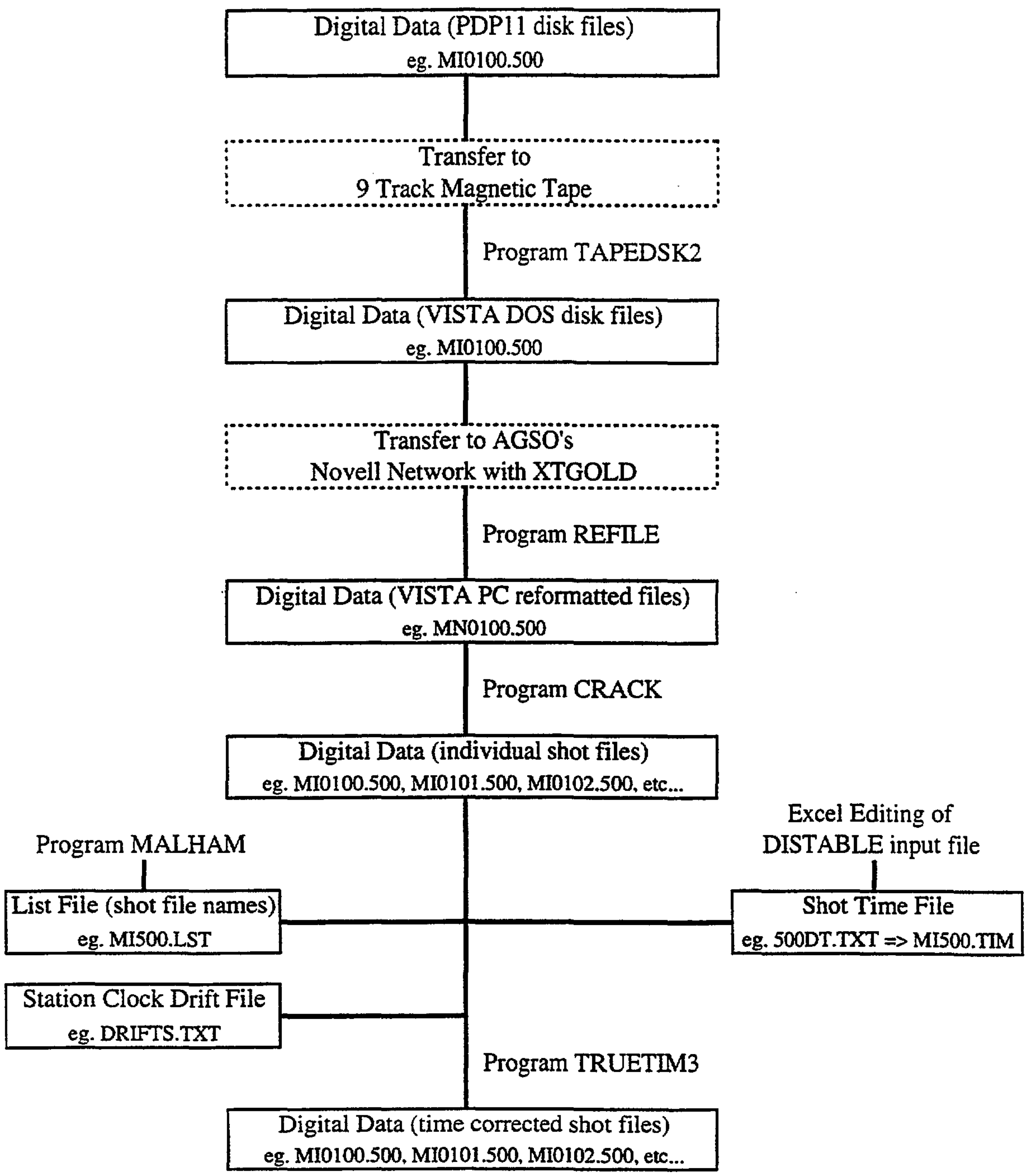

Fig. 7 - Processing stream for the handling of digital data files.

All subsequent file handling and data processing of digital data is done by PC-based programs. Hence, digitised data in the form of PDP11 disk files were transferred to a PC-system using MicroTech Conversion Systems tape control utilities in conjuction with a 9-track tape drive. The tape was read using batch files generated by Fortran program TAPEDSK2. The files were then copied over to AGSO's Novell network server system for storage and retrieval.

Digitised data was archived on AGSO's network hard discs. Due to a very large quantity of data processed (an average of 3,000 shots per traverse), individual shotpoint files are stored in a compressed (ZIP) form.

All files used in processing of Otway 1994/95 Refraction Survey are located under the **L:\OTWAY137** directory. The content of subsequent directories is described below.

Subdirectory **ARCHIVE** contains digitised shot files grouped according to unique line-station combination. By convention, digitised files from Station 1 (Milltown) corresponding to line 500 are located under the **MI500** subdirectory. Within this subdirectory there is a zip file containing final clock drift corrected shotpoint data organised in groups of approximately 2000 files at a time (with additional subdirectories named **A**, **B**, **C**, etc.). **VISTA** subdirectory contains a zip file with original PDP11 files; PC formatted versions of PDP11 files, and occasionally a batch file (used for reading the 9 track tape during data transfer). **DRIFTS** subdirectory contains files used in calculating clock corrections for a listing file containing names of all the shotpoint files and a file with shot times, both used by program TRUETIM3.FOR for calculation of time corrections. Station clock drift file is located in the OTWAY137/STATIONS/DRIFT directory. **PLOTS** subdirectory contains files with plotting parameters used in generation of record sections.

Files containing water depths are located in the **BATHYM** subdirectory.

Subdirectory **SHOTS** contains navigation and shot time data from "Rig Seismic". The navigation files are stored in the **LOCATION** subdirectory, while the shot time files are given in the **TIME** subdirectory. The files are for each individual line shot during the survey (naming convention used is ot*.asc for shot coordinate data, and s137_* for shot time data, s137_*.asc, * being the traverse number). The above files were generated from the original ship files (containing data for the whole survey) with a Unix "AWK" editor.

Subdirectory **STATIONS** contains data used in generation of Shot Time/Distance files used by the digitising program TEST97 on the PDP11.

Seismic record section production

An indication of the processing stream required to produce seismic record sections is shown in Figure 8.

All the programs listed are described by Collins et al. (1992). Some programs used during previous surveys have been modified by Igor Lukaszyk.

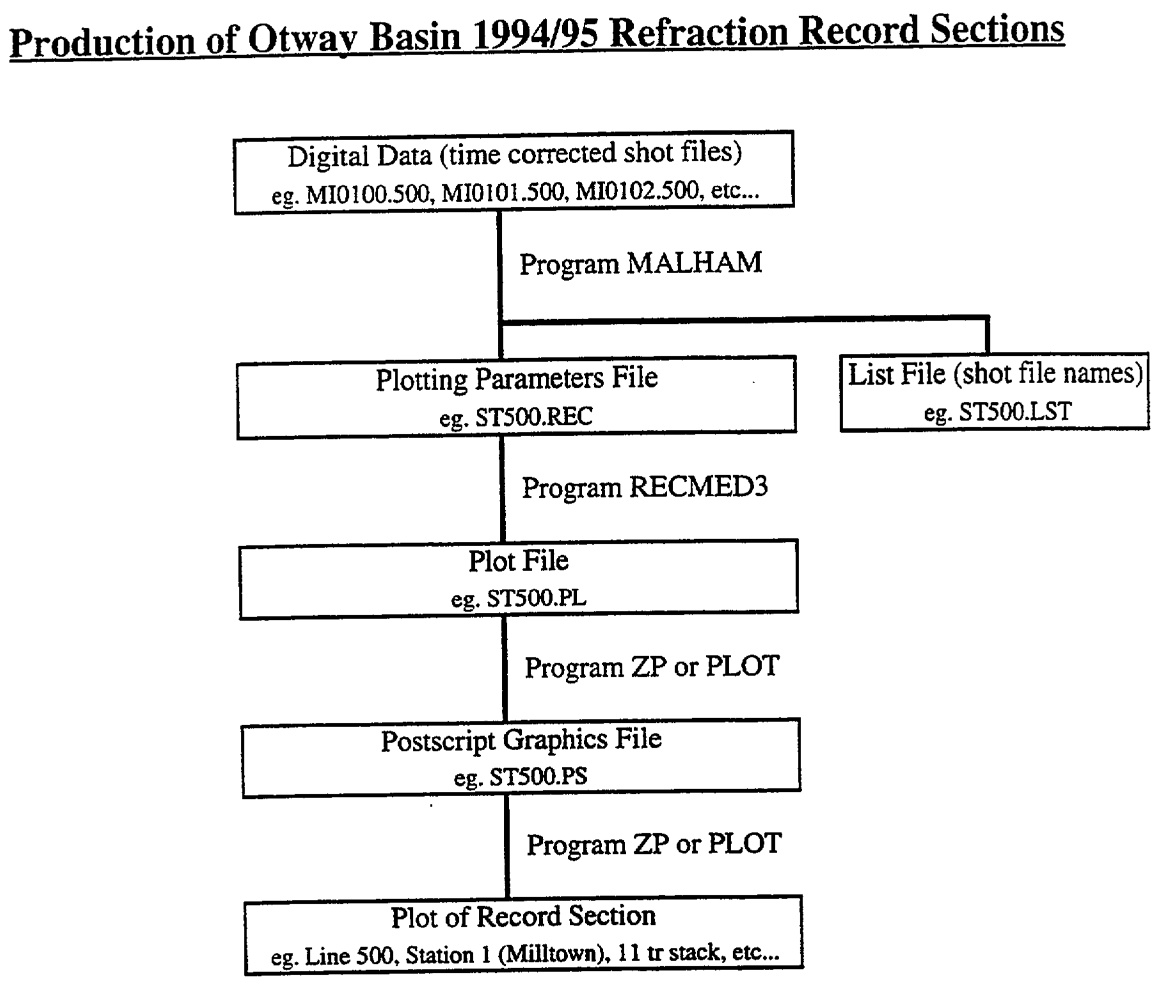

Fig. 8 - Processing stream for the production of seismic record sections.

Archiving of seismic data

The digitised data from the 1994/95 wide-angle seismic profiling in the Otway Basin occupy significant amounts of disc space. A directory has been set up on the MPSR "Onshore" network disc space which is used for the many files involved in retrieving and processing the wide-angle seismic data. The directory tree structure is shown in Figure 9.

Archiving of Otway Basin 1994/95 Refraction Data

Directory Structure used to store Survey137 refraction data:

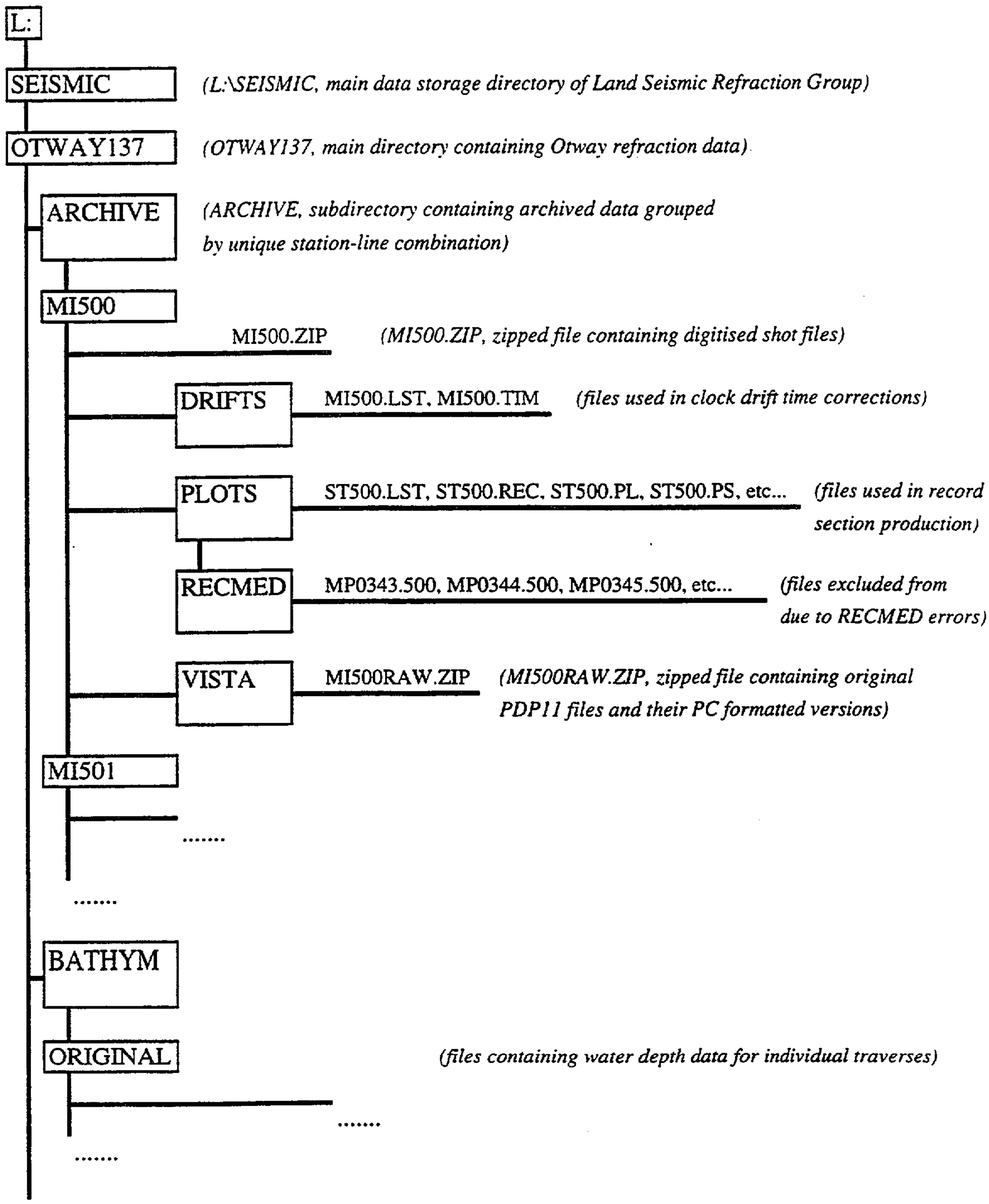

Fig. 9 - Directory structure used for the archiving of 1994/95 seismic data.

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APPENDIX 1

ONSHORE SEISMIC RECORDING SITES: LOCATIONS AND RECORDING INFORMATION

Details of the positions of the recording sites, their "active" period, and of the instrument settings on the PI recording instruments are contained in Table 1. The "active" periods at each of the recording sites is shown graphically in Figure 10 for both the December, 1994, and January, 1995, phases of the survey. Figure 11 shows maps of the site locations and some seismic reflection profiling lines near the sites.

The most significant difference between recording during December, 1994 and that during January, 1995, was in the filter settings on the TAM5 seismic amplifiers. During December, 1994, a bandpass filter of 0.01-20 Hz was set. This resulted in a significant amount of ocean-generated seismic noise being recorded, sometimes saturating the TAM5 amplifier and consequently a loss of recording. During the January, 1995, phase of the survey a 6-100 Hz bandpass filter was hard-wired into the TAM5 amplifier on all recorders, with considerable improvement in seismic noise reduction.

During the December, 1994, phase of the survey, the recorder No.16 at Mylor failed to transport tape after being set up and left apparently operational. The cause of this total failure was not determined (?power supply failure, ?battery clips). The recorder was checked on return to Canberra and operated satisfactorily during the January, 1995, phase of the survey.

Clock drift with respect to the Omega time standard was logged on all recorders when they were set up at the various sites and at the end of recording. The clock drift data noted in the field for each recorder are set out in Table 2 (“Comparator” source) and presented graphically in Figure 12. Clock drift was also checked during data retrieval by playing back short periods of clock and Omega time code on a Siemens high-speed paper recorder (Table 2 “Analog” source). These data, together with the clock errors noted in the field are presented graphically in Figure 13 for each recorder.

Timing corrections were entered into the headers of each shot file using programs/procedures outined in the chapter on data retrieval. The corrections for each file were determined by linear interpolation between points on the error plots for the recorder used (Fig. 13); both “Comparator” and “Analog” values were used.

Table 1 - Onshore seismic recording station locations, operating periods, and instrument settings for the "Rig Seismic" Survey No. 137.

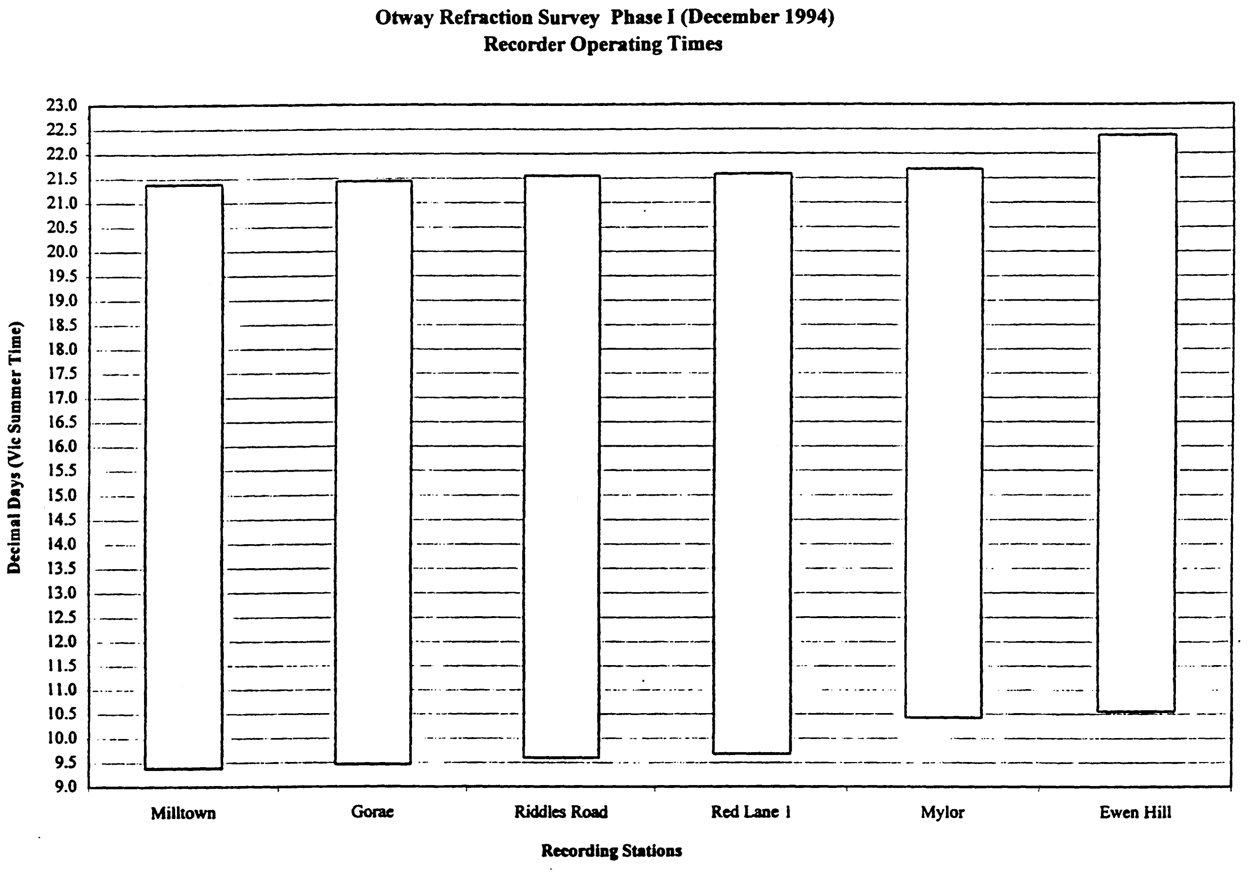
Statn No.	Site Name	Latitude Deg	Latitude Min	Longitude Deg	Longitude Min	Elev. m	Operator Name	Comments	Rec. No.	Gain dB	Filter Hz	Date On	Time On d h m	Error ms	Date Off	Time Off d h m	Error ms	Calibr.pulses d h m
Station positions and operating local times Otway Basin Refraction Phase 1																		
1	Milltown (Vic)	38	2.25	141	40.16	100	D. Finlayson	Omega dip switches set 8 sec after minute	20	84	0.01-20	9-Dec	09 09 10	995	21-Dec	21 09 19	180	09 09 25
								Clock set with respect to Omega signal										21 09 18-19
								Recorder clock on Vic Summer Time										
2	Gorae (Vic)	38	15.51	141	31.52	40	D. Finlayson	Omega dip switches set 5 sec after minute	17	84	0.01-20	9-Dec	09 11 02	008	21-Dec	21 10 30	087	09 11 14-15
								Clock set with respect to Omega signal										21 10 29-30
								Recorder clock on Vic Summer Time										
3	Riddles Road (Vic)	38	14.34	142	14.00	70	D. Finlayson	Omega dip switches set 8 sec after minute	21	84	0.01-20	9-Dec	09 14 12	993	21-Dec	21 13 05	215	09 14 30-31
								Clock set with respect to Omega signal										21 13 05-06
								Recorder clock on Vic Summer Time										
								Stubborn start on tape transport but locks in OK										
								Looks OK										
4	Red Lane 1 (Vic)	38	2.66	142	14.00	125	D. Finlayson	Omega dip switches set 8 sec after minute	18	84	0.01-20	9-Dec	09 16 10	997	21-Dec	21 13 54	391	09 16 08-09
								Clock set with respect to Omega signal										21 13 55-56
								Recorder clock on Vic Summer Time										
								Looks OK										
5	Mylor (Vic)	38	31.70	142	54.82	93	D. Finlayson	Omega dip switches set 5 sec after minute	16	84	0.01-20	10-Dec	10 10 07	997	21-Dec	21 16 23	n/a	10 10 12-13
								Clock set with respect to Omega signal										
								Recorder clock on Vic Summer Time										
								Total failure No tape transport since setup										
6	Ewen Hill (Vic)	38	16.22	143	4.06	137	D. Finlayson	Omega dip switches set 5 sec after minute	19	84	0.01-20	10-Dec	10 13 08	002	22-Dec	22 08 53	910	10 13 29
								Clock set with respect to Omega signal										22 08 50-53
								Recorder clock on Vic Summer Time										
								Looks OK										
Station positions and operating local times Otway Basin Refraction Phase 2																		
1	Noolook (SA)	37	0.20	139	51.55	-10	E. Chudyk	Omega dip switches set 8 sec after minute	18	84	6-100	9-Jan	09 12 30	982	22-Jan	22 13 01	494	09 12 25
								Clock set with respect to Telecom time signal										22 13 08
								At setup clock retarded towards the incorrect second, ie.										
								clock approximately 1 sec slow (1.0664 sec)										
								Recorder clock on Vic Summer Time										
2	Deep Swamp (SA)	36	45.07	140	13.55	50	E. Chudyk	Omega dip switches set 5 sec after minute	19	90	6-100	9-Jan	09 16 53	995	18-Jan	18 17 34	004	09 16 53
								Clock set with respect to Telecom time signal										18 17 30
								Recorder clock on Vic Summer Time										
3	Jip Jip (SA)	36	29.18	140	10.83	40	E. Chudyk	Omega dip switches set 5 sec after minute	17	90	6-100	9-Jan	09 20 29	044	17-Jan	17 10 03	097	09 20 30
								Clock set with respect to Telecom time signal										12 10 02
								Recorder clock on Vic Summer Time										

Table 1 (continued)

Statn No.	Site Name	Latitude Deg	Latitude Min	Longitude Deg	Longitude Min	Elev. m	Operator Name	Comments	Rec. No.	Gain dB	Filter Hz	Date On	Time On d h m	Error ms	Date Off	Time Off d h m	Error ms	Calibr.pulses d h m
4	Taratap Road	36	38.99	139	53.52	-61	E. Chudyk	Omega dip switches set to 0 sec	20	90	6-100	11-Jan	11 13 00	003	17-Jan	17 08 06	087	11 15 00
	(SA)							Clock set with respect to Telecom time signal										17 08 05
								Recorder clock on SA Summer Time										
								Good site, close to granite										
5	Woakwine (SA)	37	22.70	140	2.26	37	E. Chudyk	Omega dip switches set to 0 sec	16	84	6-100	13-Jan	13 17 47	020	22-Jan	22 14 44	029	13 17 45
								Clock set with respect to Telecom time signal										
								Recorder clock on SA Summer Time at setup,										
								reset to Vic Summer Time at 17:00 on 16-Jan										
								Recorder Gain 90dB at 17:00 on 16-Jan										
								Initial problems with the clock and radio										
6	East Avenue	37	2.80	140	16.63	-4	E. Chudyk	Omega dip switches set to 0 sec	21	90	6-100	15-Jan	15 18 21	010	18-Jan	18 19 07	004	15 18 19
	(SA)							Clock set with respect to Telecom time signal										18 18 34
								Recorder clock on SA Summer Time at setup,										
								reset to Vic Summer Time at 15:29 on 16-Jan										
								Recorder Gain 96dB at 15:29 on on 16-Jan										
								Next to a quiet bitumen road, no traffic										
7	Milltown (Vic)	38	2.25	141	40.16	100	E. Chudyk	Omega dip switches set 5 sec after minute	17	96	6-100	17-Jan	17 15 10	003	20-Jan	21 18 55	029	17 15 09
								Clock set with respect to Telecom time signal										30 18 55
								Recorder clock on Vic Summer Time										
								Site ripped by dozer; just missed seismometer										
								and cable										
8	Kongorong (SA)	37	52.53	140	35.86	63	E. Chudyk	Omega dip switches set to 0 sec	20	90	6-100	17-Jan	17 17 16	002	22-Jan	22 16 34	019	18 14 54
								Clock set with respect to Telecom time signal										
								Recorder clock on SA Summer Time										
								Recorder Gain 96dB at 10:35 on 19-Jan,										
								back to 90dB at 11:32 on 20-Jan										
								Windy site										
9	Riddles Road	38	14.34	142	14.00	70	E. Chudyk	Omega dip switches set to 0 sec	19	96	6-100	19-Jan	19 14 57	008	23-Jan	23 12 27	997	19 14 55
	(Vic)							(as opposed to Deep Swamp, when they were on 5 sec)										23 12 29
								Clock set with respect to Telecom time signal										
								Recorder clock on Vic Summer Time										
								Dip switches have been set to give a 16.022										
								sec delay (annual Sidereal Time correction)										
10	Mylor (Vic)	38	31.70	142	54.82	93	E. Chudyk	Omega dip switches set to 0 sec	21	96	6-100	19-Jan	19 18 23	002	21-Jan	21 10 00	n/a	19 18 22
								Clock set with respect to Telecom time signal										
								Recorder clock on Vic Summer Time										
								Station stopped working around 10:00 on 22-Jan										
								Station restarted after mechanical adjustments	21	96	6-100	21-Jan	21 13 30	003	23-Jan	23 16 14	077	21 13 28

Table 1 (continued)

Statn	Site	Latitude		Longitude		Elev.	Operator	Comments	Rec.	Gain	Filter	Date On	Time On	Error	Date Off	Time Off	Error	Calibr.pulses
No.	Name	Deg	Min	Deg	Min	m	Name		No.	dB	Hz		d h m	ms		d h m	ms	d h m
11	Red Lane 2 (Vic)	38	2.97	142	20.94	133	E. Chudyk	Omega dip switches set 5 sec after minute	17	90	6-100	20-Jan	20 21 29	000	23-Jan	23 13 47	020	20 21 31
								Clock set with respect to Telecom time signal										
								Recorder clock on Vic Summer Time										



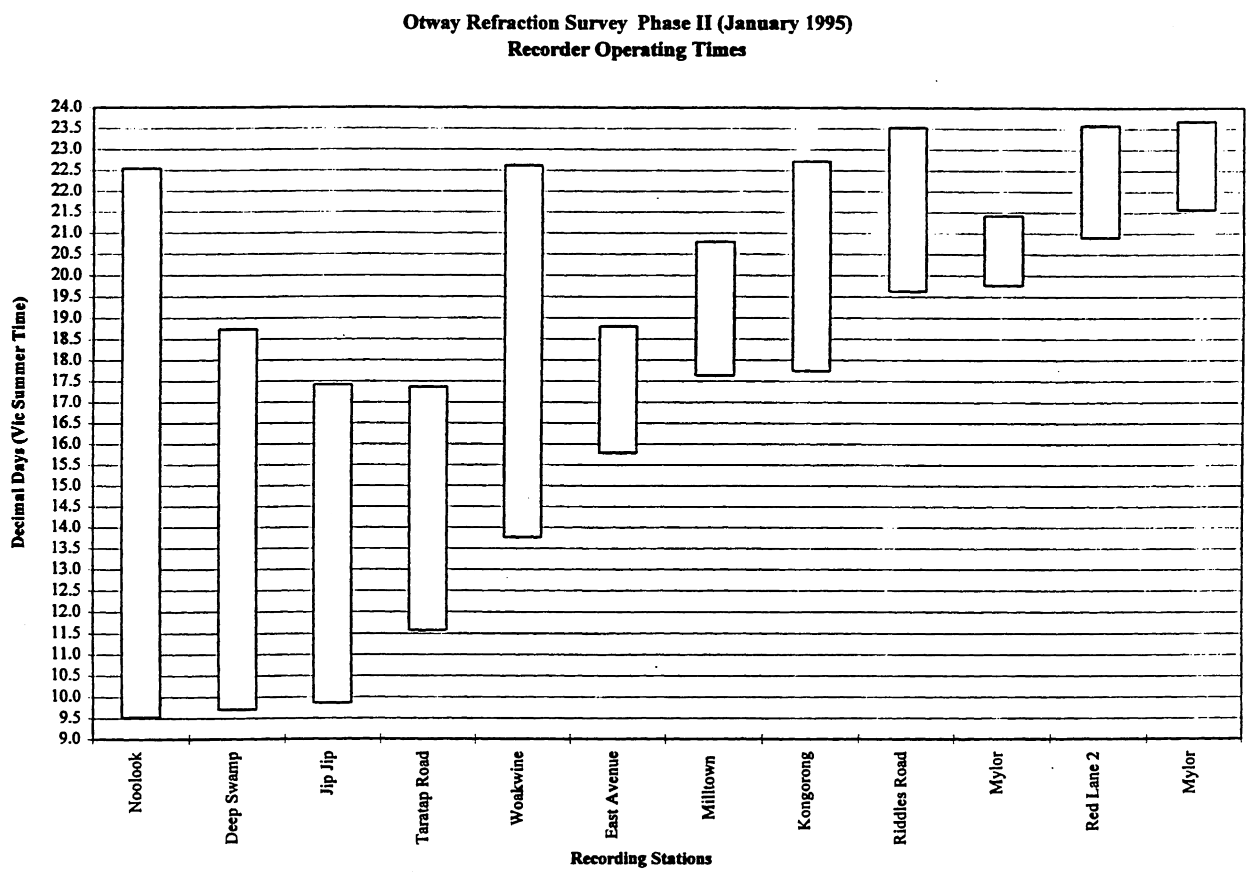


Fig. 10 - Graphical representation of onshore seismic station recording periods during "Rig Seismic" Survey No.137.

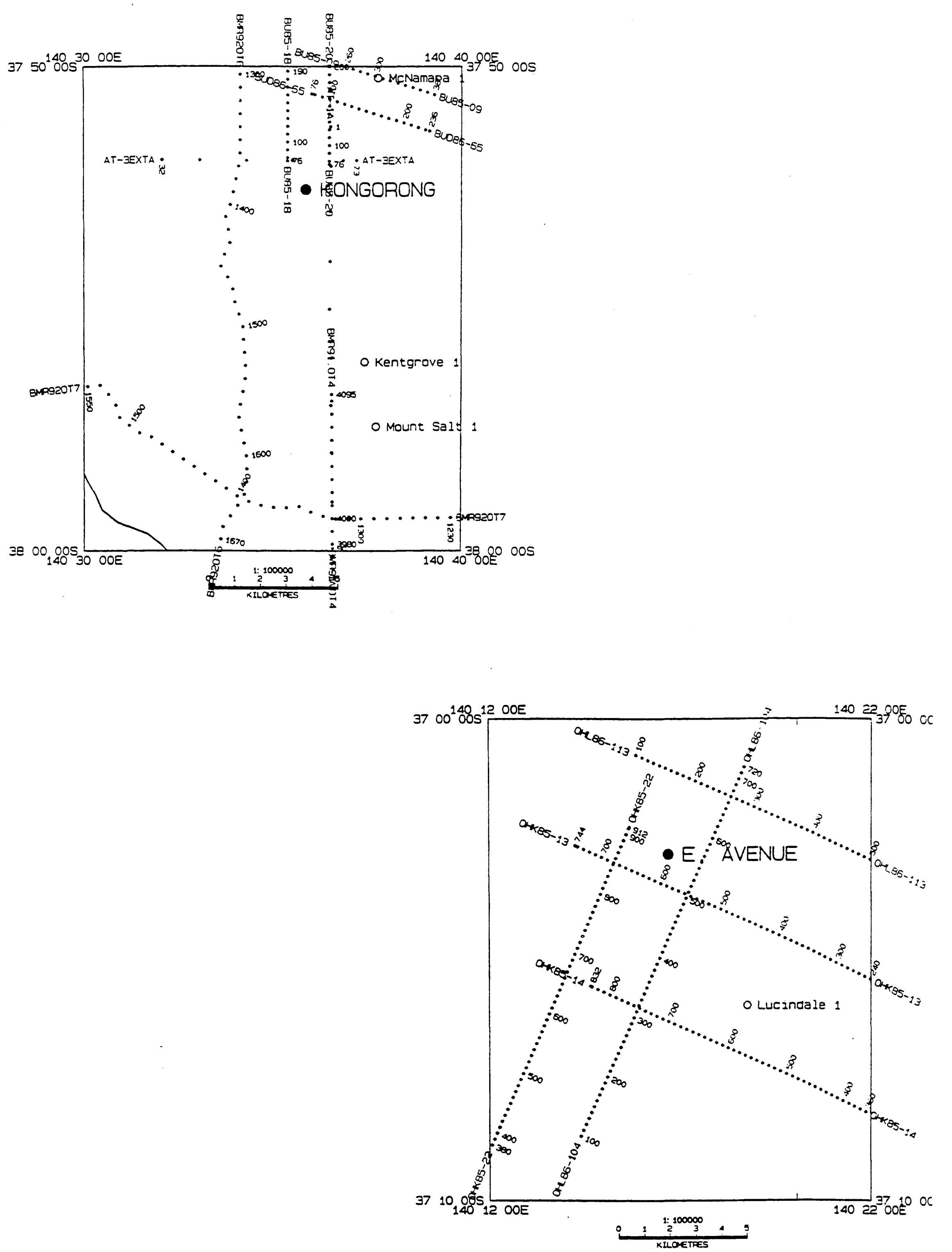
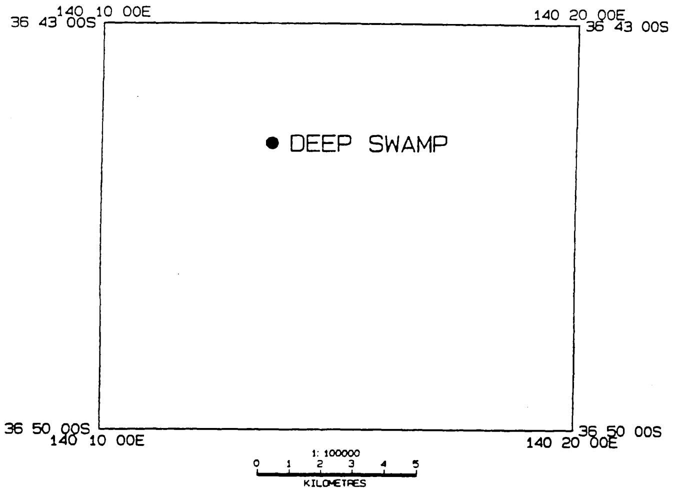
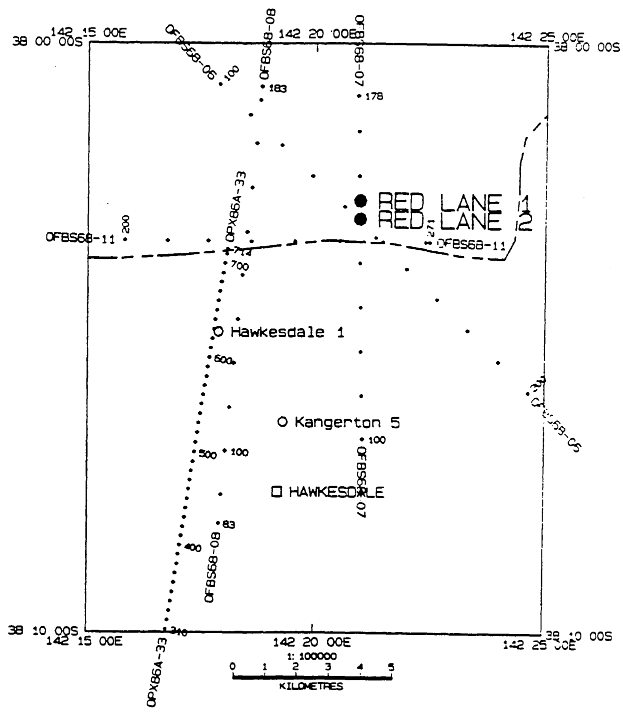


Fig. 11 - Location maps for onshore seismic recording stations and adjacent seismic reflection profiles.





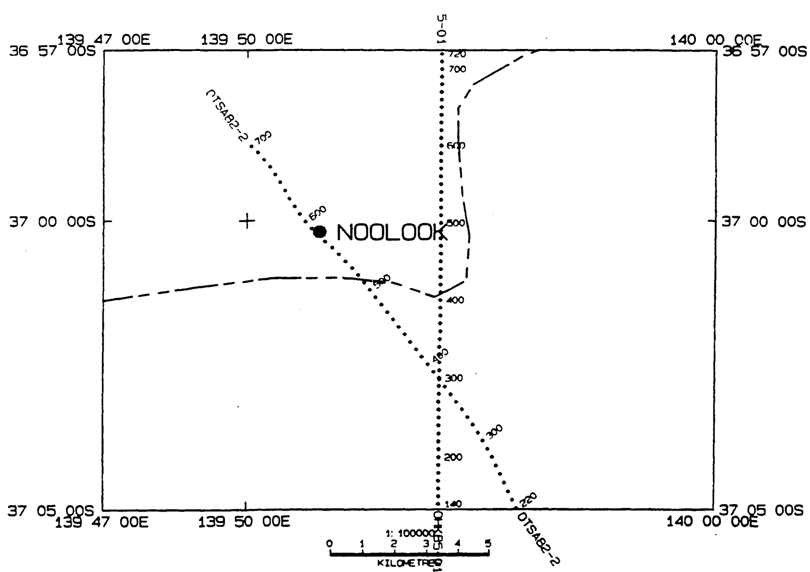


Fig. 11 (continued)

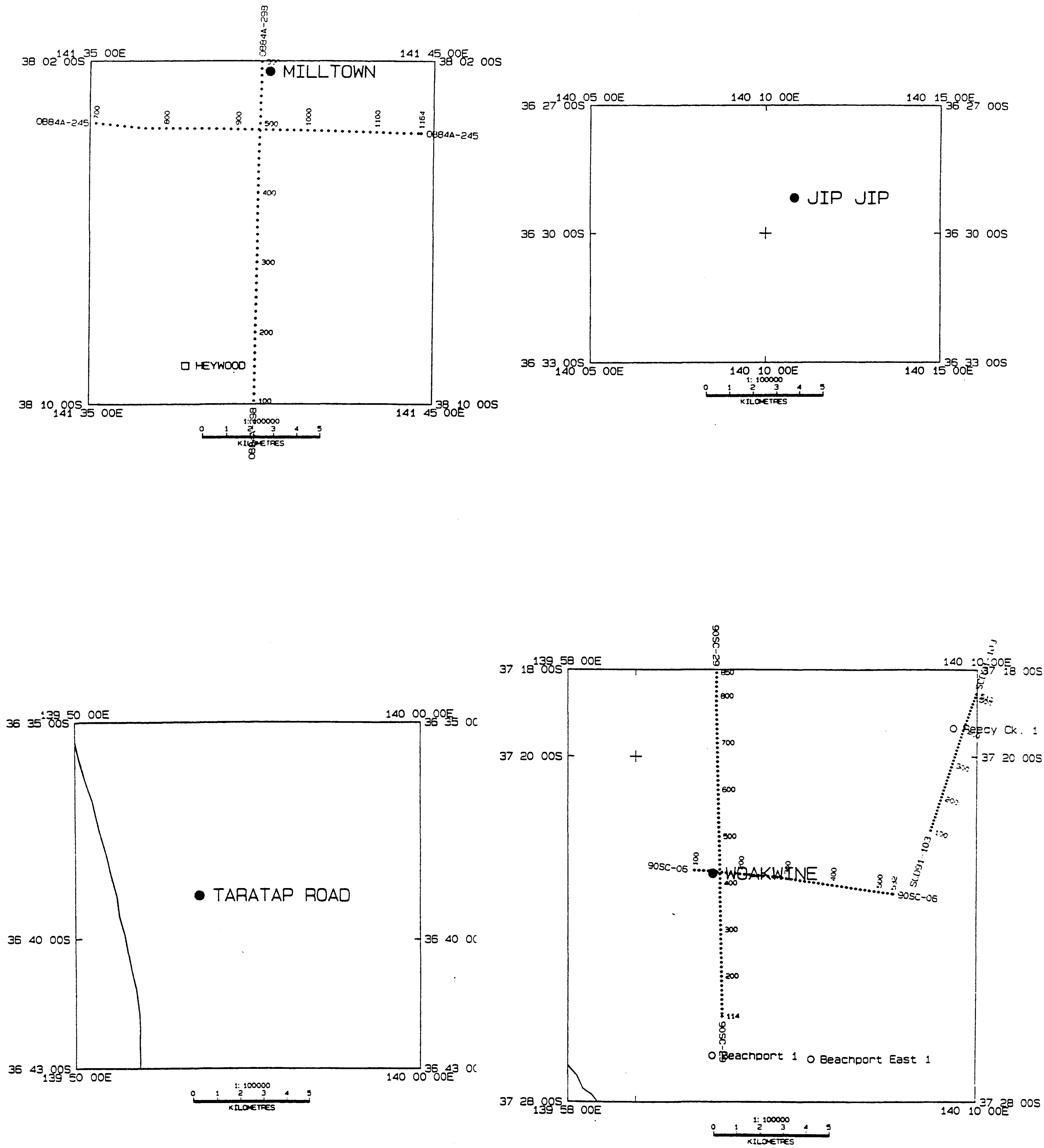


Fig. 11 (continued)

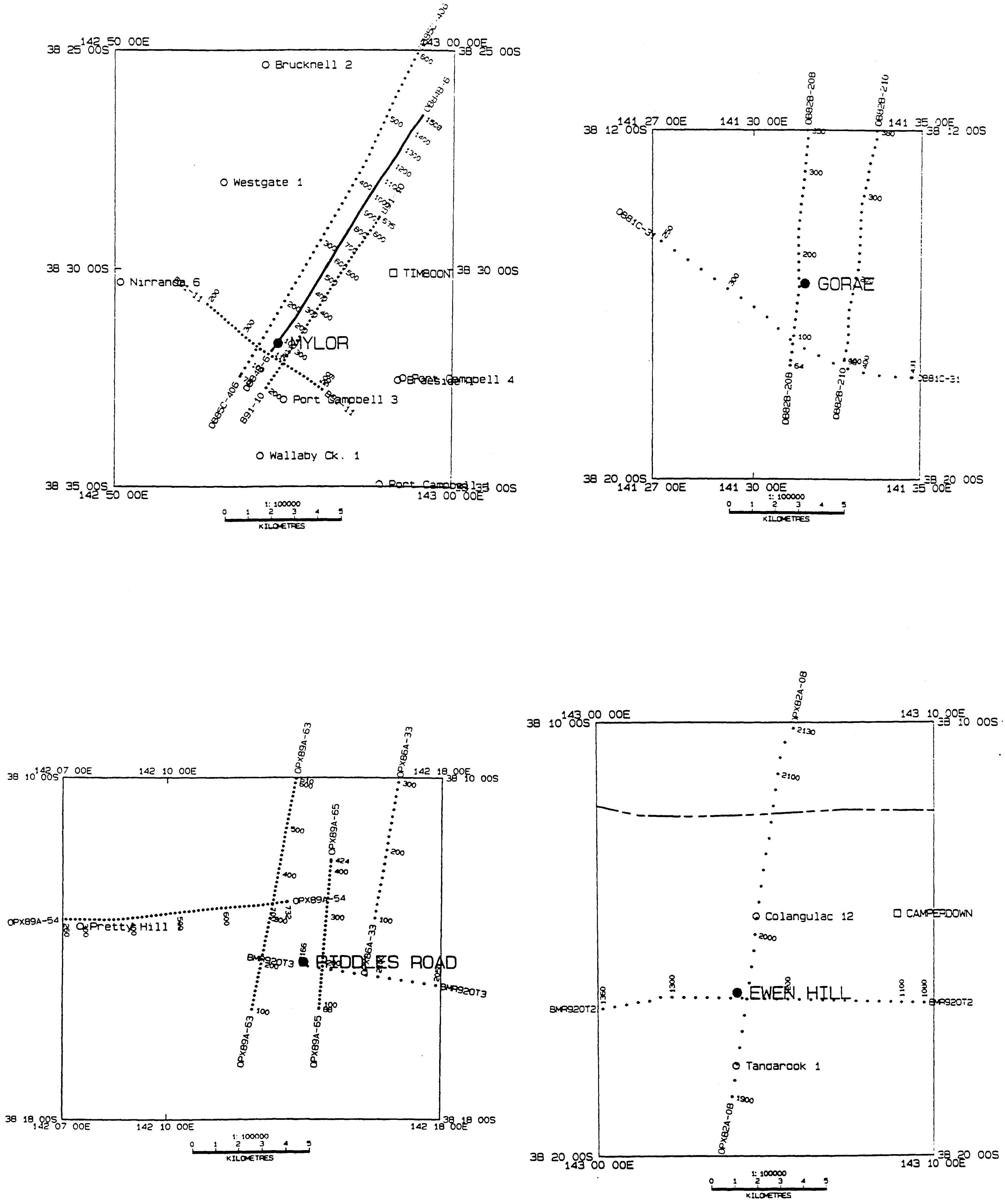


Fig. 11 (continued)

DECEMBER, 1994

Site No	Site Name	Rec. No.	Vic Summer Time d	h	m	Time dec days	Error s	Corrected Error, s	Source
1	Milltown	20	9	9	10	9.3819	0.995	-0.005	Comparator
1	Milltown	20	10	14	16	10.5944	-0.087	-0.087	Analog
1	Milltown	20	15	08	37	15.3590	0.087	0.087	Analog
1	Milltown	20	19	15	58	19.6653	0.102	0.102	Analog
1	Milltown	20	21	02	20	21.0972	0.180	0.180	Analog
1	Milltown	20	21	9	19	21.3882	0.180	0.180	Comparator
2	Gorae	17	9	11	2	9.4597	0.008	0.008	Comparator
2	Gorae	17	10	07	56	10.3306	0.023	0.023	Analog
2	Gorae	17	16	00	56	16.0389	0.042	0.042	Analog
2	Gorae	17	19	17	15	19.7188	0.083	0.083	Analog
2	Gorae	17	21	10	30	21.4375	0.087	0.087	Comparator
3	Riddles Road	21	9	14	12	9.5917	0.993	-0.007	Comparator
3	Riddles Road	21	10	9	38	10.4014	0.036	0.036	Analog
3	Riddles Road	21	13	12	19	13.5132	0.076	0.076	Analog
3	Riddles Road	21	16	23	24	16.9750	0.142	0.142	Analog
3	Riddles Road	21	21	2	4	21.0861	0.194	0.194	Analog
3	Riddles Road	21	21	13	5	21.5451	0.215	0.215	Comparator
4	Red Lane 1	18	9	16	10	9.6736	0.997	-0.003	Comparator
4	Red Lane 1	18	10	11	23	10.4743	0.025	0.025	Analog
4	Red Lane 1	18	13	17	18	13.7208	0.240	0.240	Analog
4	Red Lane 1	18	17	12	36	17.5250	0.538	0.538	Analog
4	Red Lane 1	18	20	7	1	20.2924	0.564	0.564	Analog
4	Red Lane 1	18	21	13	54	21.5792	0.391	0.391	Comparator
6	Ewen Hill	19	10	13	8	10.5472	0.002	0.002	Comparator
6	Ewen Hill	19	11	21	24	11.8917	0.000	0.000	Analog
6	Ewen Hill	19	15	11	24	15.4750	-0.030	-0.030	Analog
6	Ewen Hill	19	18	02	47	18.1160	-0.054	-0.054	Analog
6	Ewen Hill	19	20	19	02	20.7931	-0.079	-0.079	Analog
6	Ewen Hill	19	22	8	53	22.3701	0.910	-0.090	Comparator

Table 2 - Onshore seismic recorder clock corrections during the "Rig Seismic" Survey No. 137.

Site No	Site Name	Rec. No.	Vic Summer Time d	h	m	Time dec days	Error s	Corrected Error, s	Source
1	Noolook (SA)	18	9	12	30	9.5208333	0.982	-0.018	Comparator
1	Noolook (SA)	18	10	4	5	10.170139	-1.168	0.168	Analog
1	Noolook (SA)	18	12	18	43	12.779861	-1.583	0.583	Analog
1	Noolook (SA)	18	15	4	9	15.172917	-1.691	0.691	Analog
1	Noolook (SA)	18	17	6	23	17.265972	-1.954	0.954	Analog
1	Noolook (SA)	18	20	22	10	20.923611	-2.094	1.094	Analog
1	Noolook (SA)	18	21	21	43	21.904861	-2.504	1.504	Analog
1	Noolook (SA)	18	22	13	1	22.542361	0.494	1.494	Comparator
2	Deep Swamp (SA)	19	9	16	53	9.7034722	0.995	-0.005	Comparator
2	Deep Swamp (SA)	19	10	3	30	10.145833	0.043	0.043	Analog
2	Deep Swamp (SA)	19	12	20	34	12.856944	-0.008	-0.008	Analog
2	Deep Swamp (SA)	19	17	7	42	17.320833	0.014	0.014	Analog
2	Deep Swamp (SA)	19	18	17	34	18.731944	0.004	0.004	Comparator
3	Jip Jip (SA)	17	9	20	29	9.8534722	0.044	0.044	Comparator
3	Jip Jip (SA)	17	9	21	2	9.8763889	0.048	0.048	Analog
3	Jip Jip (SA)	17	10	3	58	10.165278	0.048	0.048	Analog
3	Jip Jip (SA)	17	11	9	12	11.383333	0.054	0.054	Analog
3	Jip Jip (SA)	17	12	16	1	12.667361	0.060	0.060	Analog
3	Jip Jip (SA)	17	13	19	7	13.796528	0.070	0.070	Analog
3	Jip Jip (SA)	17	16	9	19	16.388194	0.093	0.093	Analog
3	Jip Jip (SA)	17	17	10	3	17.41875	0.097	0.097	Comparator
4	Taratap Road (SA)	20	11	13	30	11.5625	0.003	0.003	Comparator
4	Taratap Road (SA)	20	12	10	0	12.416667	0.016	0.016	Analog
4	Taratap Road (SA)	20	14	22	35	14.940972	0.082	0.082	Analog
4	Taratap Road (SA)	20	17	2	57	17.122917	0.128	0.128	Analog
4	Taratap Road (SA)	20	17	8	36	17.358333	0.087	0.087	Comparator
5	Woakwine (SA)	16	13	18	17	13.761806	0.020	0.020	Comparator
5	Woakwine (SA)	16	14	13	18	14.554167	0.031	0.031	Analog
5	Woakwine (SA)	16	21	10	17	21.428472	0.045	0.045	Analog
5	Woakwine (SA)	16	22	13	47	22.574306	0.046	0.046	Analog
5	Woakwine (SA)	16	22	14	44	22.613889	0.029	0.029	Comparator
6	East Avenue (SA)	21	15	18	51	15.785417	0.010	0.010	Comparator
6	East Avenue (SA)	21	15	21	28	15.894444	0.068	0.068	Analog

Table 2 (continued)

JANUARY, 1995

Site No	Site Name	Rec. No.	Vic Summer Time d	h	m	Time dec days	Error s	Corrected Error, s	Source
6	East Avenue (SA)	21	17	7	26	17.309722	0.025	0.025	Analog
6	East Avenue (SA)	21	18	11	45	18.489583	0.031	0.031	Analog
6	East Avenue (SA)	21	18	19	7	18.796528	0.004	0.004	Comparator
7	Milltown (Vic)	17	17	15	10	17.631944	0.003	0.003	Comparator
7	Milltown (Vic)	17	18	1	37	18.067361	0.009	0.009	Analog
7	Milltown (Vic)	17	19	22	17	19.928472	0.020	0.020	Analog
7	Milltown (Vic)	17	20	18	55	20.788194	0.029	0.029	Comparator
8	Kongorong (SA)	20	17	17	46	17.740278	0.002	0.002	Comparator
8	Kongorong (SA)	20	22	17	4	22.711111	0.019	0.019	Comparator
9	Riddles Road (Vic)	19	19	14	57	19.622917	0.008	0.008	Comparator
9	Riddles Road (Vic)	19	20	18	1	20.750694	0.116	0.116	Analog
9	Riddles Road (Vic)	19	22	18	52	22.786111	-0.004	-0.004	Analog
9	Riddles Road (Vic)	19	23	12	27	23.51875	0.997	-0.003	Comparator
10	Mylor (Vic)	21	19	18	23	19.765972	0.002	0.002	Comparator
10	Mylor (Vic)	21	20	4	17	20.178472	0.009	0.009	Analog
10	Mylor (Vic)	21	20	5	8	20.213889	0.008	0.008	Analog
10	Mylor (Vic)	21	21	10	0	21.416667	n/a	n/a	Comparator
11	Red Lane 2 (Vic)	17	20	21	29	20.895139	0.000	0.000	Comparator
11	Red Lane 2 (Vic)	17	21	11	17	21.470139	0.003	0.003	Analog
11	Red Lane 2 (Vic)	17	22	23	30	22.979167	0.016	0.016	Analog
11	Red Lane 2 (Vic)	17	23	13	47	23.574306	0.020	0.020	Comparator
12	Mylor (Vic)	21	21	13	30	21.5625	0.003	0.003	Comparator
12	Mylor (Vic)	21	21	16	50	21.701389	0.012	0.012	Analog
12	Mylor (Vic)	21	21	22	59	21.957639	0.014	0.014	Analog
12	Mylor (Vic)	21	22	22	42	22.945833	0.049	0.049	Analog
12	Mylor (Vic)	21	23	16	14	23.676389	0.077	0.077	Comparator

Table 2 (continued)

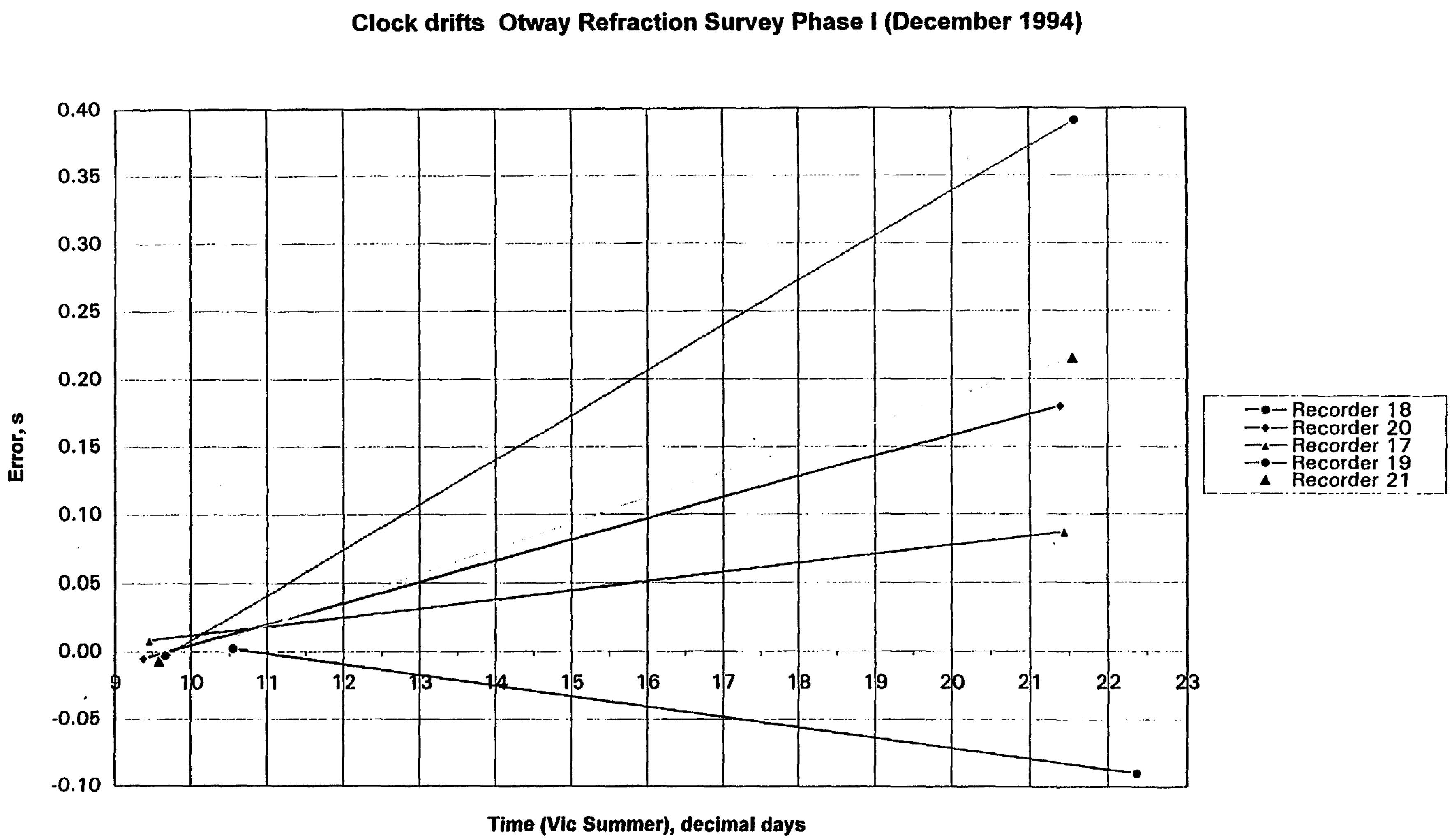


Fig. 12 - Graphical representation of in-field "Comparator" clock errors for onshore seismic recorders during the "Rig Seismic" Survey No.137.

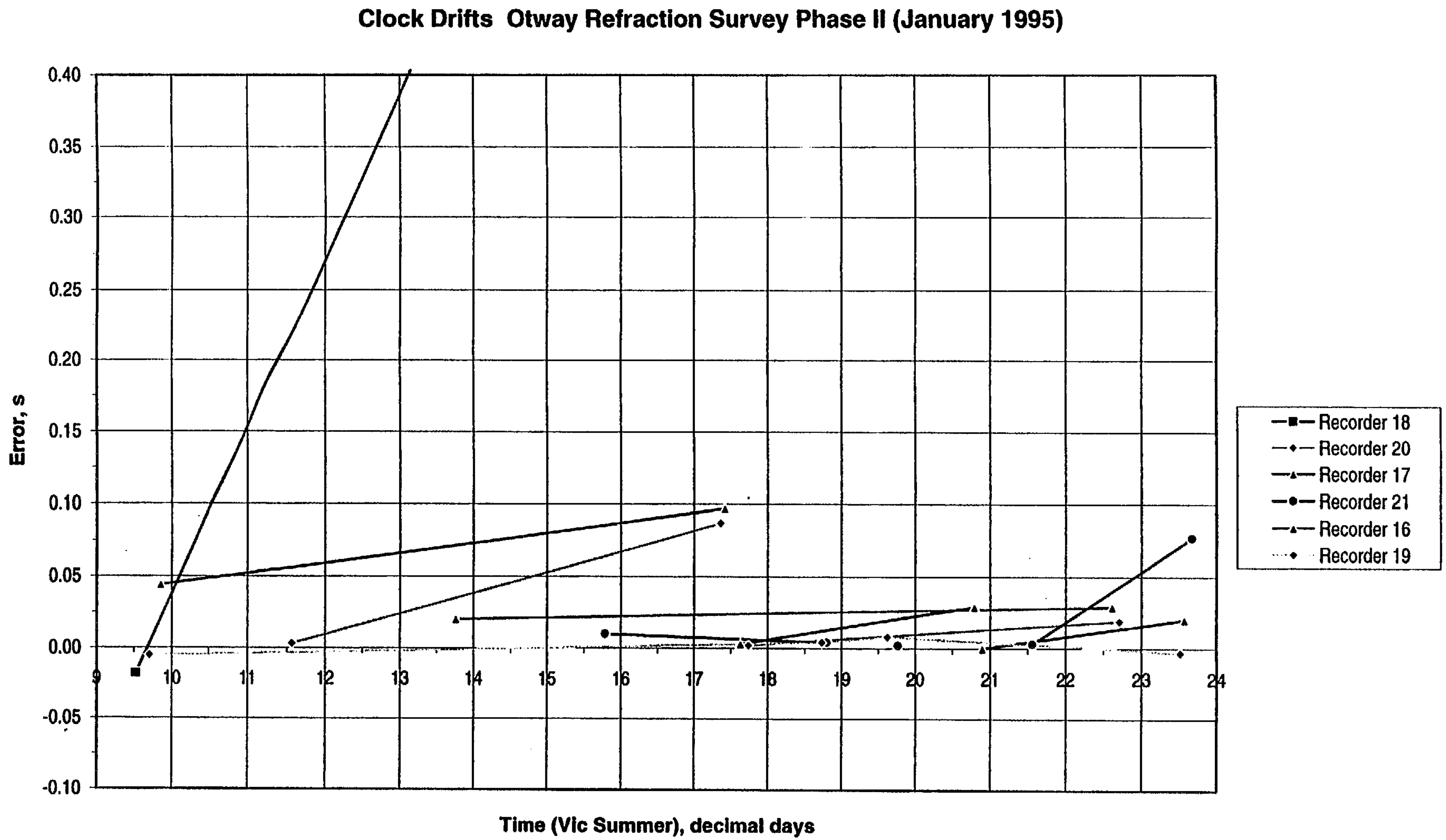


Fig. 12 (continued)

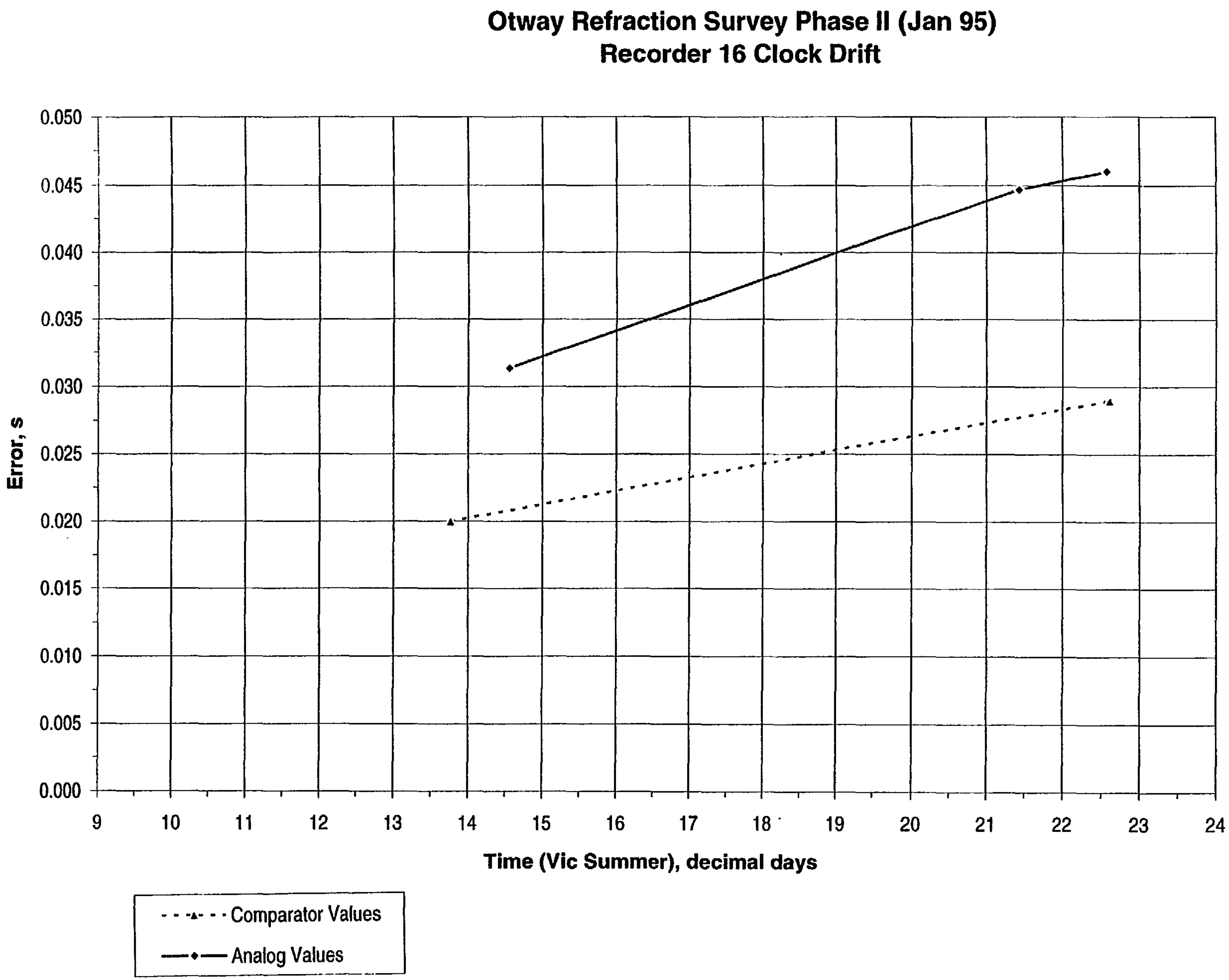


Fig. 13 - Clock errors for seismic recorders during the December, 1994, and January, 1995, phases of the Otway Basin survey. Both in-field "comparator" and playback "analogue" errors are plotted.

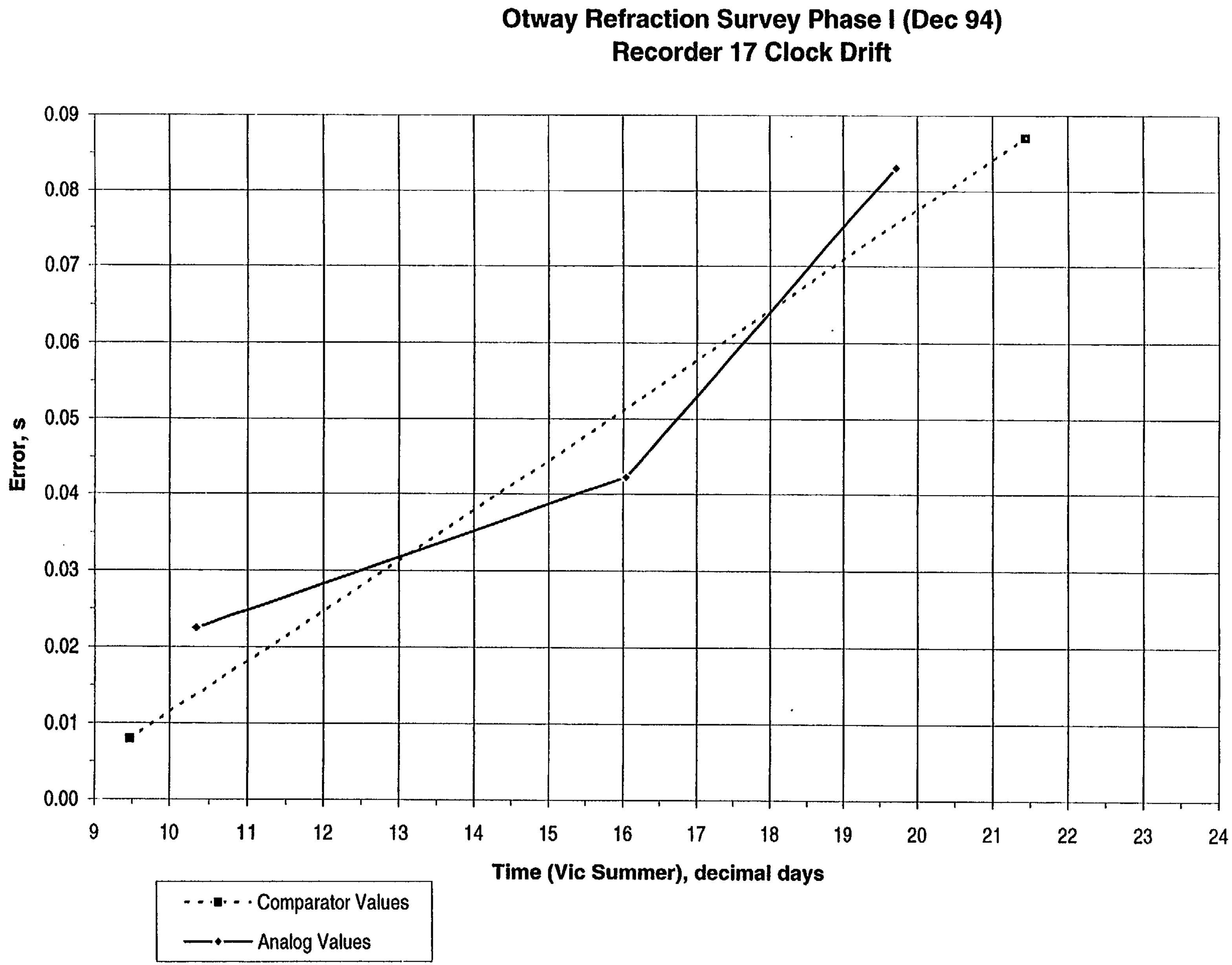


Fig. 13 (continued)

Otway Refraction Survey Phase II (Jan 95)
Recorder 17 Clock Drift

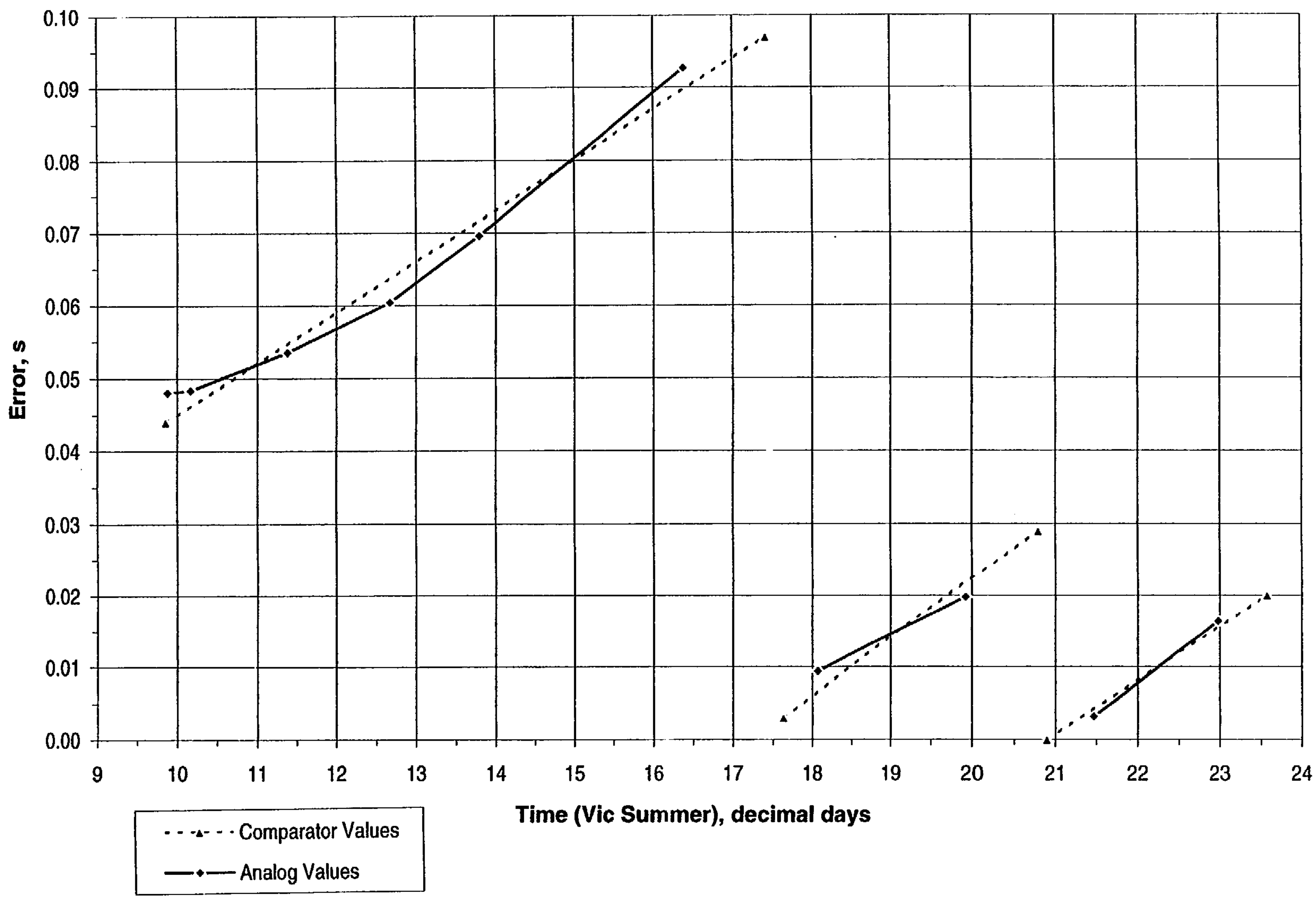


Fig. 13 (continued)

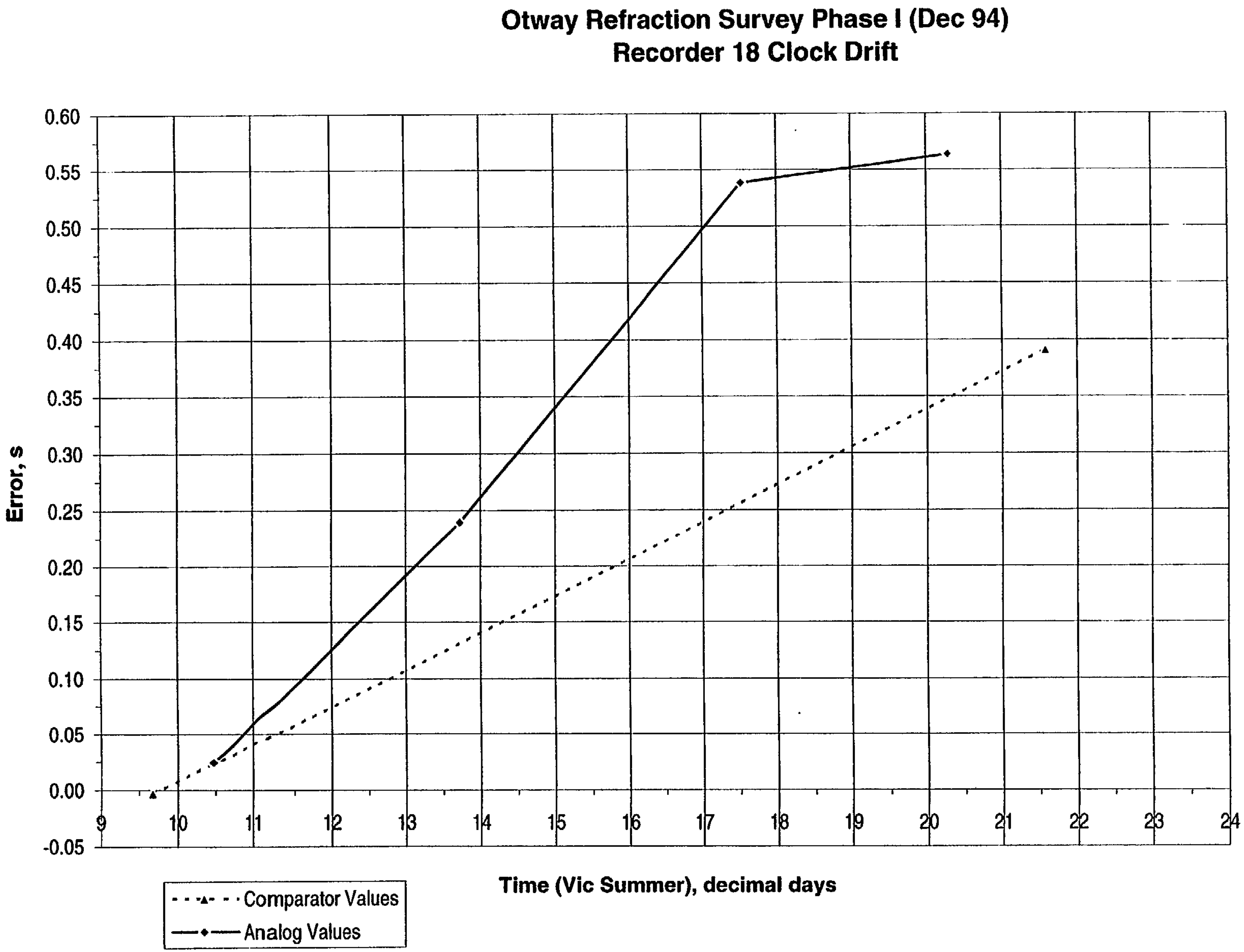


Fig. 13 (continued)

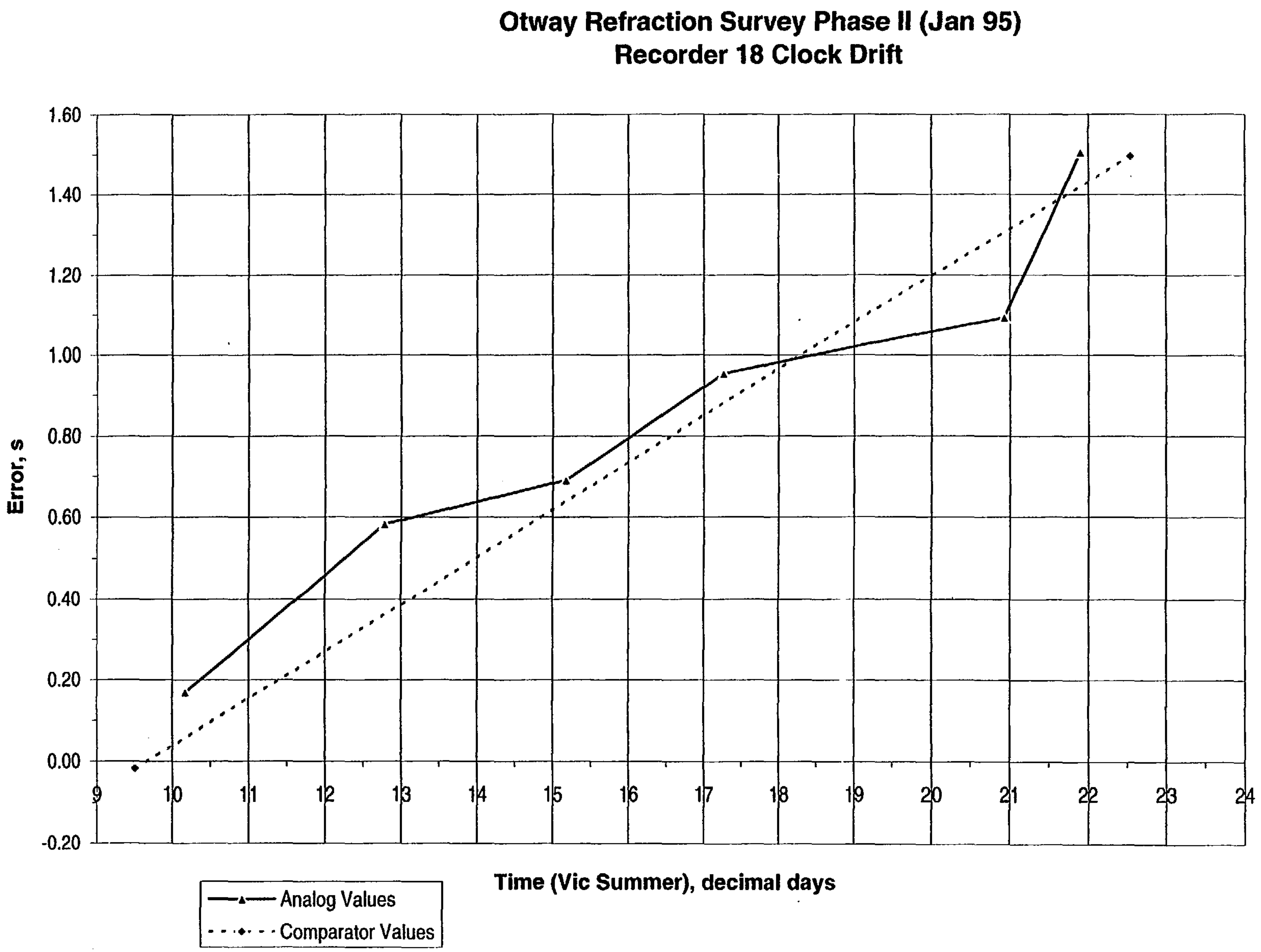


Fig. 13 (continued)

Otway Refraction Survey Phase I (Dec 94)
Recorder 19 Clock Drift

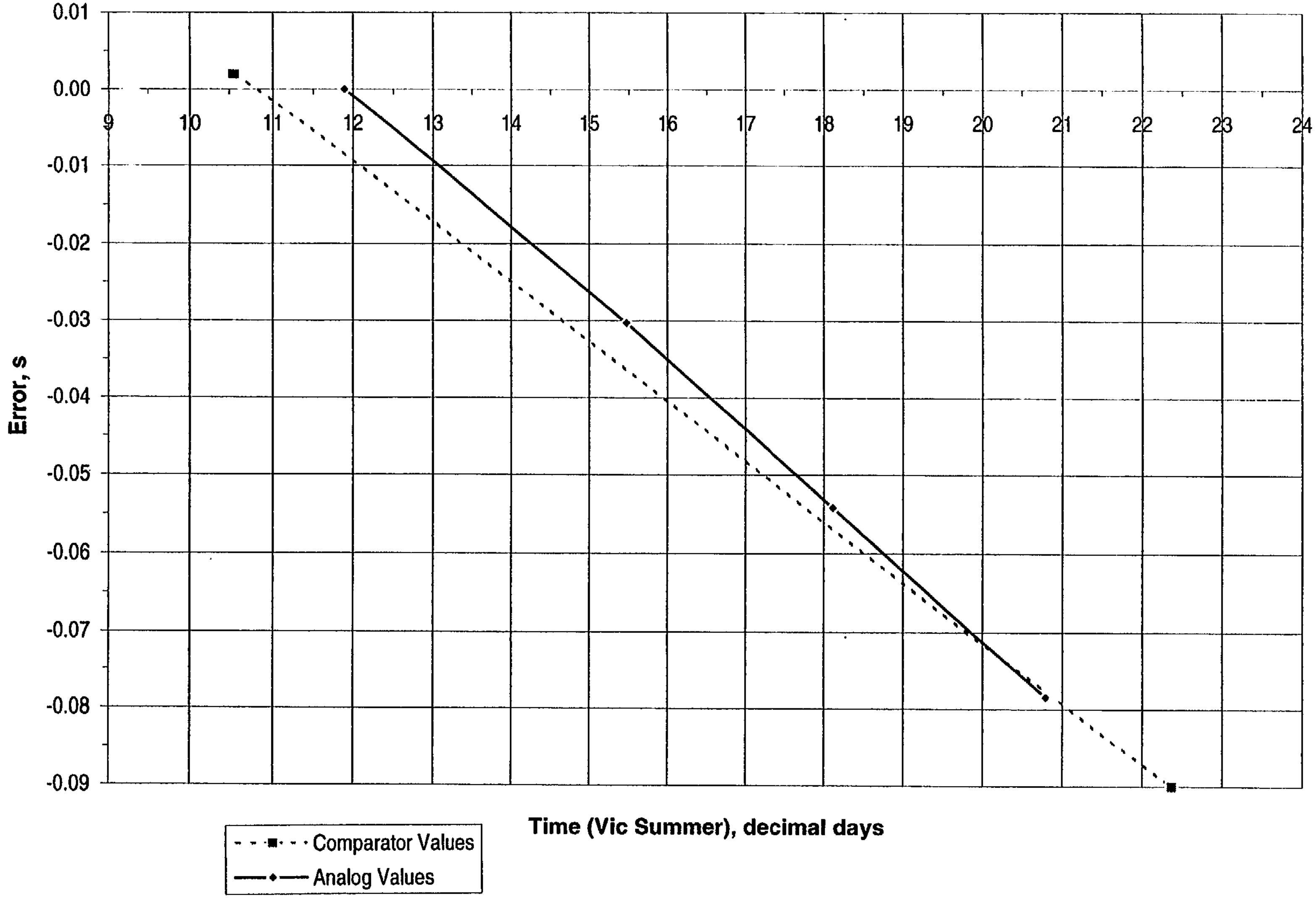


Fig. 13 (continued)

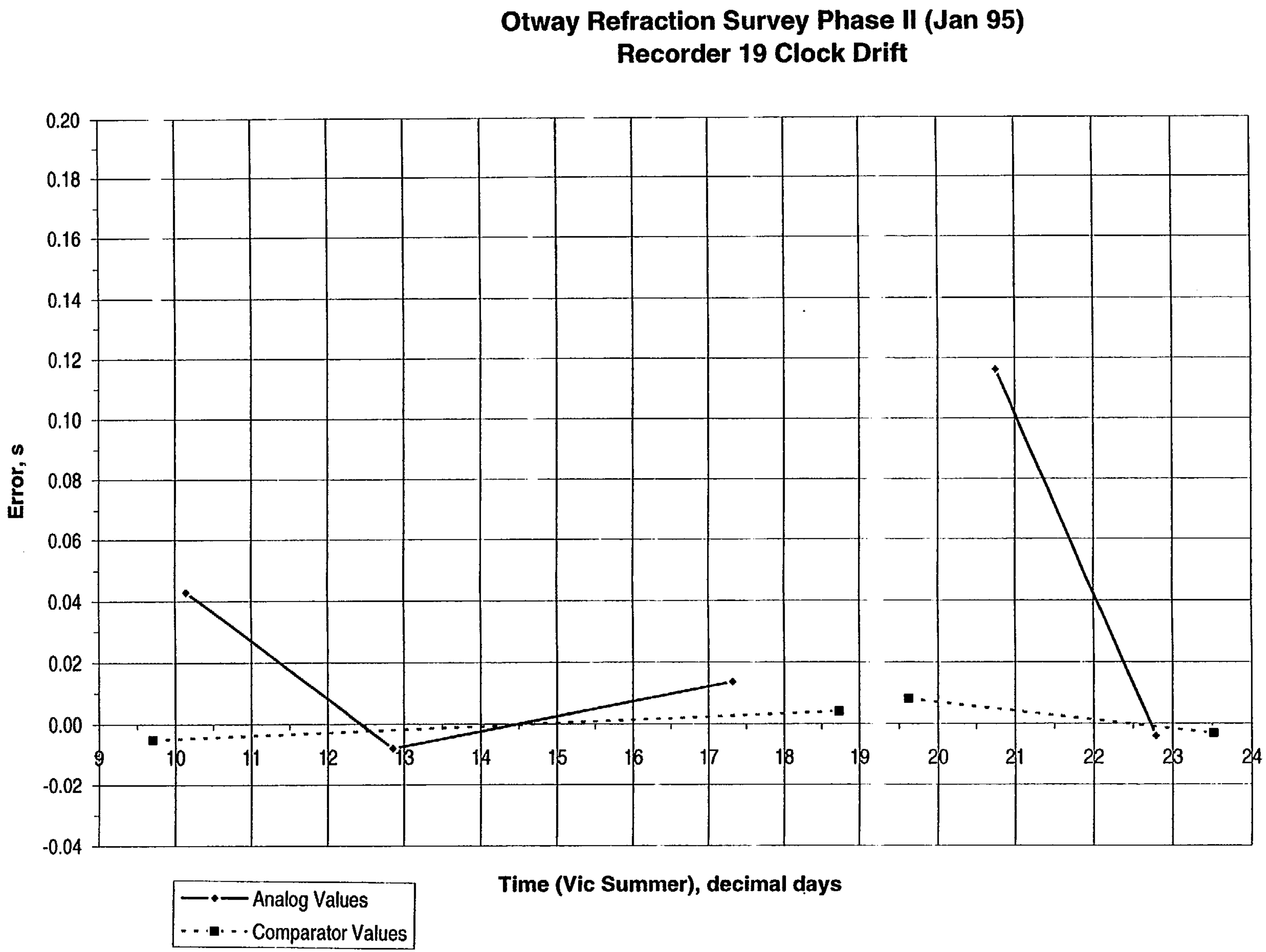


Fig. 13 (continued)

Fig. 13 (continued)

Otway Refraction Survey Phase I (Dec 94)
Recorder 20 Clock Drift

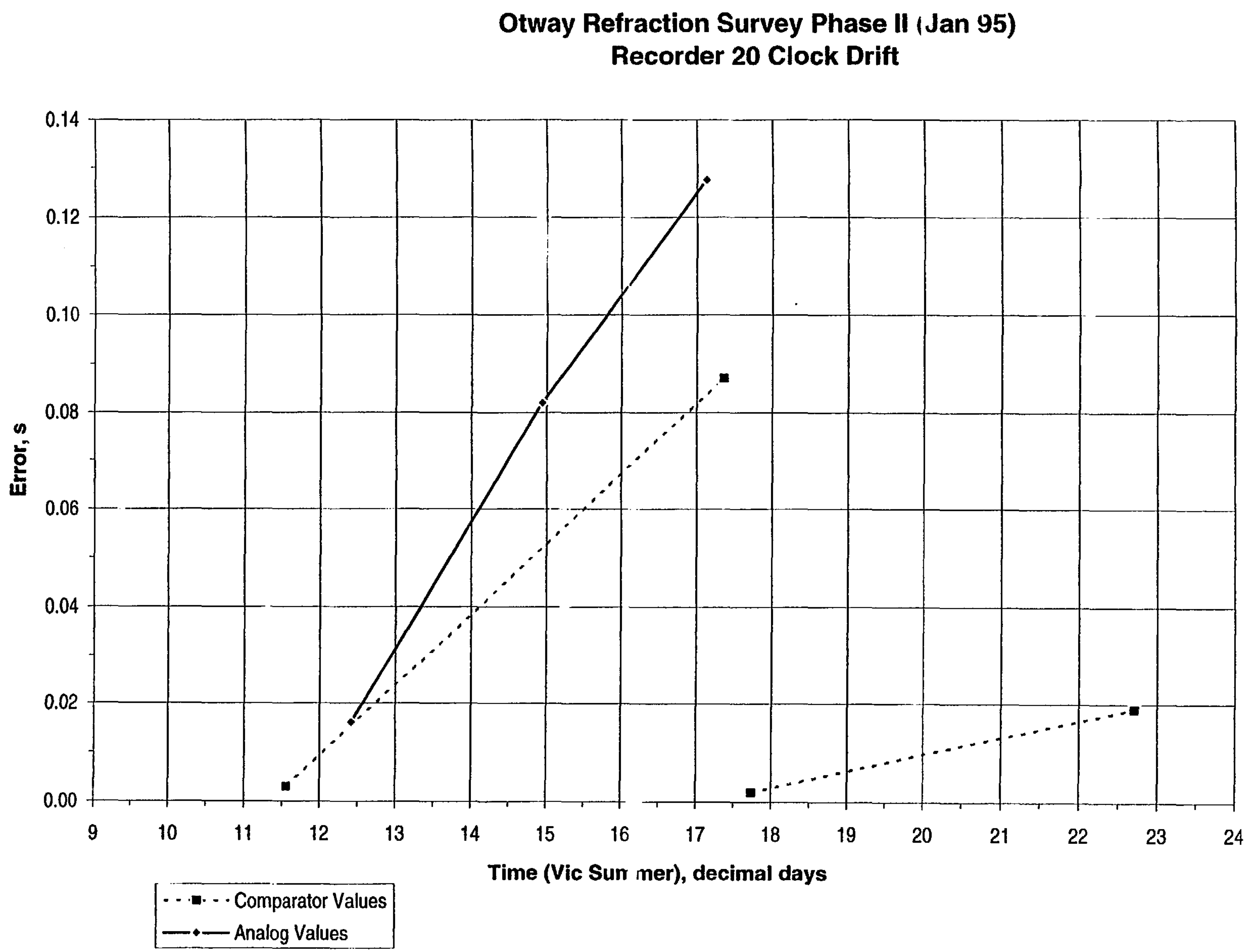


Fig. 13 (continued)

Otway Refraction Survey Phase I (Dec 94)
Recorder 21 Clock Drift

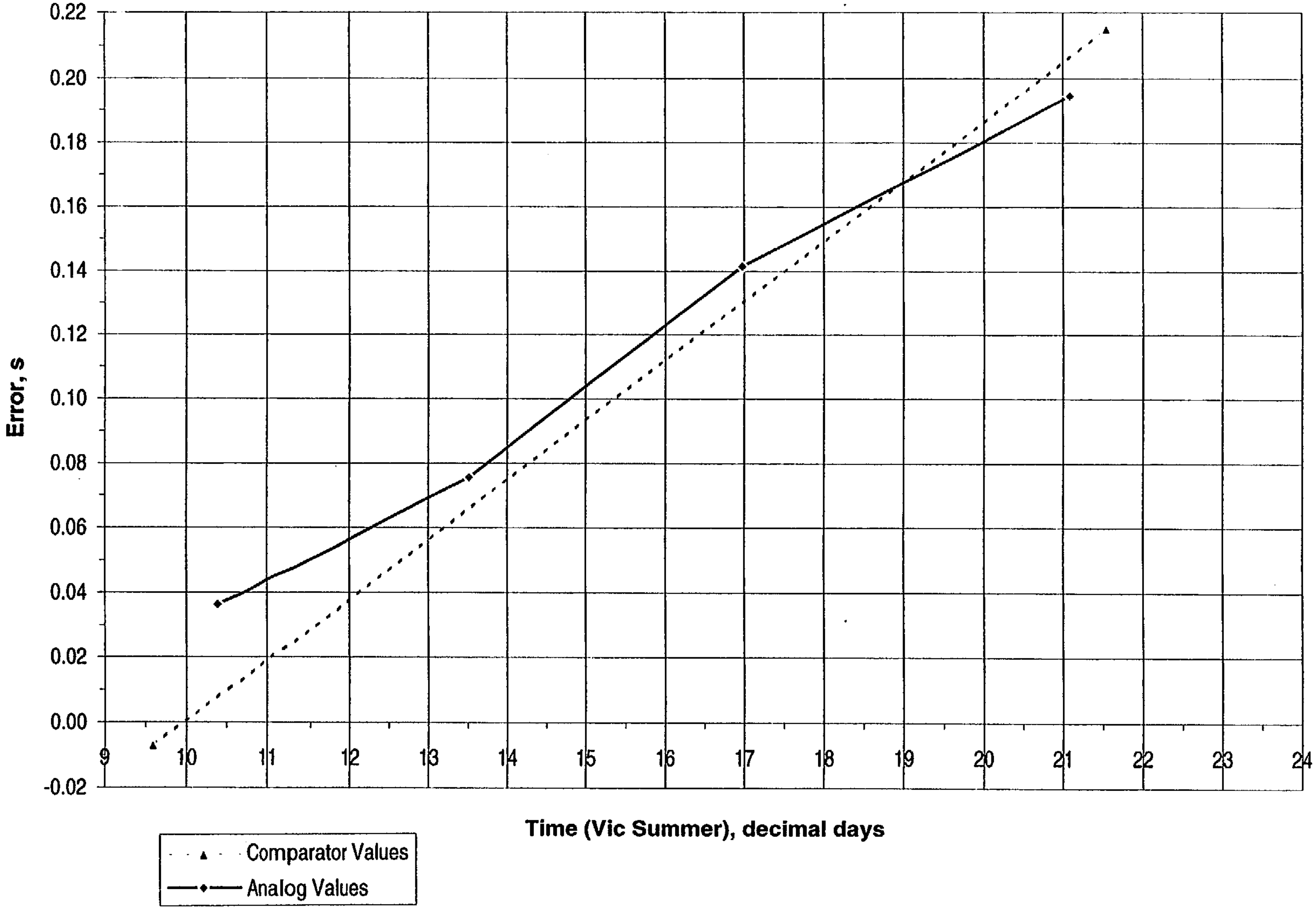


Fig. 13 (continued)

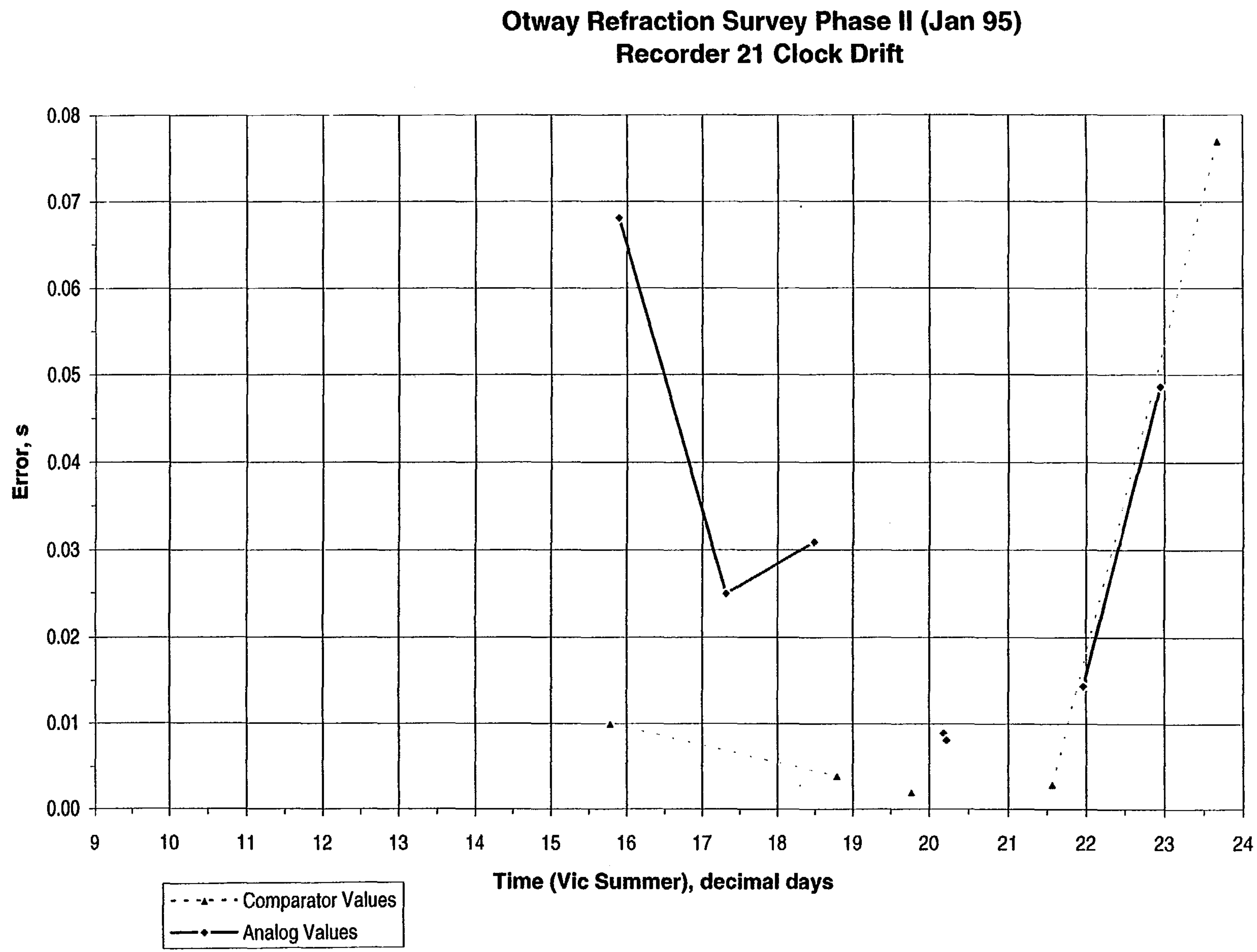


Fig. 13 (continued)

APPENDIX 2

"RIG SEISMIC" OPERATIONS AND SYSTEMS

The following summary information is taken from the comprehensive operations report for the "Rig Seismic" Survey No.137 by Glen Cassim et al.(1995).

The general survey parameters are as follows:

Client:	AGSO
Survey Number:	137 (Phase I & II)
Survey Name:	Otway Basin, S-E Australia: Deep Crustal Seismic Data Acquisition
Area:	Otway Basin, South-Eastern Australia
Survey Vessel:	R/V Rig Seismic
Type of Survey:	Seismic
Mode of Shooting:	2D
Primary Nav:	Racal 1 Multifix Version 1.3 DGPS
Secondary Nav:	Racal 2 Multifix Version 2.0 DGPS
Streamer:	Single Analogue Streamer
Streamer Length:	4800 Metre
Streamer Depth:	10.0 metres (Seq 001 - 021) 13.0 metres (Seq 022 - 023)
Energy Source:	Single High Pressure Air Source Array
Energy Source Type:	Sleeve Guns - 3000 cubic inches - 1800 psi
Energy Source Depth:	10.0 metres
Shot Point Interval:	50.0 metres
Nominal Fold:	4800 %
Record Length:	16 seconds
Number of Lines:	13
Line Sequences:	23
Kilometres:	3464.900
Time Delay From Start of Record To Gun Timebreak:	60.0 milliseconds

The project coordinates supplied to the vessel prior to sailing were based on the WGS-84 geodetic datum. The positioning of the vessel was achieved using Racal Multifix 1 and Multifix II DGPS positioning systems. The data from these systems was passed to the DAS Navigation Sytem used to position the vessel and trailing equipment. The traverse accuracy was estimated to be better than 5 metres. The seismic source was fired at every 50 metres of vessel travel along each traverse.

Seismic recording on 192 channels (plus 16 auxiliary channels) in the streamer was achieved using the MUSIC Recording System with 2 millisecond sample rate and a 16 second record length.

Table 3 contains details of the shooting times of the various "Rig Seismic" lines. These are set out both in Universal Time (UT) and in Victorian Summer Time, the latter being used to set the clocks on the onshore recorders in most cases. At some of the South Australian recording sites, the clocks were set to South Australian Summer Time which is 30 mins behind that in Victoria. Figure 14 shows the shooting times of the various lines graphically.

Details of the seismic recording system, seismic streamer, seismic source, navigation system, and vessel, are contained in Tables 4, 5, 6, 7, and 8 on the following pages taken from Survey No.137 Operations Report. Also, Figures 15, 16 and 17 contain examples of the recording geometry, streamer geometry, and source geometry, again taken from the "Rig Seismic" Operations Report.

Rig Seismic line shooting times Otway Basin Refraction Phase 1								
Line No.	Start SP	Start Date (UT)	Start Time (UT) d h m	Finish SP	Finish Date (UT)	Finish Time (UT) d h m	Start Time (Vic) d h m	Finish Time (Vic) d h m
137/000100	100	30-Nov	30 10 34	5141	1-Dec	01 12 53	**30 21 34**	**01 23 53**
	5143	1-Dec	01 12 53	5145	1-Dec	01 12 54	**01 23 53**	**01 23 54**
	5146	1-Dec	01 12 54	10940	2-Dec	02 18 29	**01 23 54**	**03 05 54**
137/000200	100	3-Dec	03 12 24	2623	4-Dec	04 02 15	**03 23 24**	**04 13 15**
137/000300	100	4-Dec	04 18 12	2535	5-Dec	05 06 45	**05 05 12**	**05 17 45**
137/000301	100	5-Dec	05 19 43	4703	6-Dec	06 19 23	**06 06 43**	**07 06 23**
137/000400	100	8-Dec	08 22 27	2492	9-Dec	09 11 04	**09 09 27**	**09 22 04**
137/000401	3432	9-Dec	09 19 25	3969	9-Dec	09 22 30	**10 06 25**	**10 09 30**
137/000500	100	10-Dec	10 06 09	3303	10-Dec	10 22 50	**10 17 09**	**11 09 50**
137/000501	4243	11-Dec	11 01 48	6082	11-Dec	11 11 14	**11 12 48**	**11 22 14**
137/000600	100	12-Dec	12 07 45	3001	12-Dec	12 23 22	**12 23 45**	**13 10 22**
137/000700	100	14-Dec	14 07 45	5406	15-Dec	15 14 16	**14 18 45**	**16 01 16**
137/000402	5100	16-Dec	16 05 52	6877	16-Dec	16 16 20	**16 16 52**	**17 03 20**
137/000800	100	17-Dec	17 00 45	3518	17-Dec	17 19 22	**17 11 45**	**18 06 22**
137/000601	4941	18-Dec	18 05 29	6829	18-Dec	18 16 07	**18 16 29**	**19 03 07**
137/000900	100	18-Dec	18 18 39	5999	20-Dec	20 01 44	**19 05 39**	**20 12 44**
137/000900	6000	20-Dec	20 01 44	7177	20-Dec	20 07 49	**20 12 44**	**20 18 49**

Table 3 - Shooting times for the "Rig Seismic" profiles during Survey No.137.
(Note that ship tracks for January, 1995, were initially designated as having survey number 151)

Rig Seismic line shooting times Otway Basin Refraction Phase 2								
151/001000	100	12-Jan	12 05 27	4295	13-Jan	13 03 10	**12 16 27**	**13 14 10**
151/001100	100	14-Jan	14 01 15	3510	14-Jan	14 19 30	**14 12 15**	**15 06 30**
151/000101	5100	15-Jan	15 09 46	6695	15-Jan	15 18 32	**15 20 46**	**16 05 32**
151/000201	5100	16-Jan	16 00 13	6778	16-Jan	16 09 00	**16 11 13**	**16 20 00**
151/000801	5100	16-Jan	16 13 16	6880	16-Jan	16 23 15	**17 00 16**	**17 10 15**
151/001200	100	17-Jan	17 05 41	1114	17-Jan	17 11 05	**17 16 41**	**17 22 05**
151/001200	1116	17-Jan	17 11 05	4308	18-Jan	18 04 35	**17 22 05**	**18 15 35**
151/000502	10100	19-Jan	19 02 39	10305	19-Jan	19 03 54	**19 13 39**	**19 14 54**
151/000502	10310	19-Jan	19 03 56	14068	20-Jan	20 03 42	**19 14 56**	**20 14 42**
151/000503	15020	20-Jan	20 15 56	15634	21-Jan	21 09 18	**21 02 56**	**21 20 18**
151/001300	100	21-Jan	21 20 55	1689	22-Jan	22 05 41	**22 07 55**	**22 16 41**

Table 3 (continued)

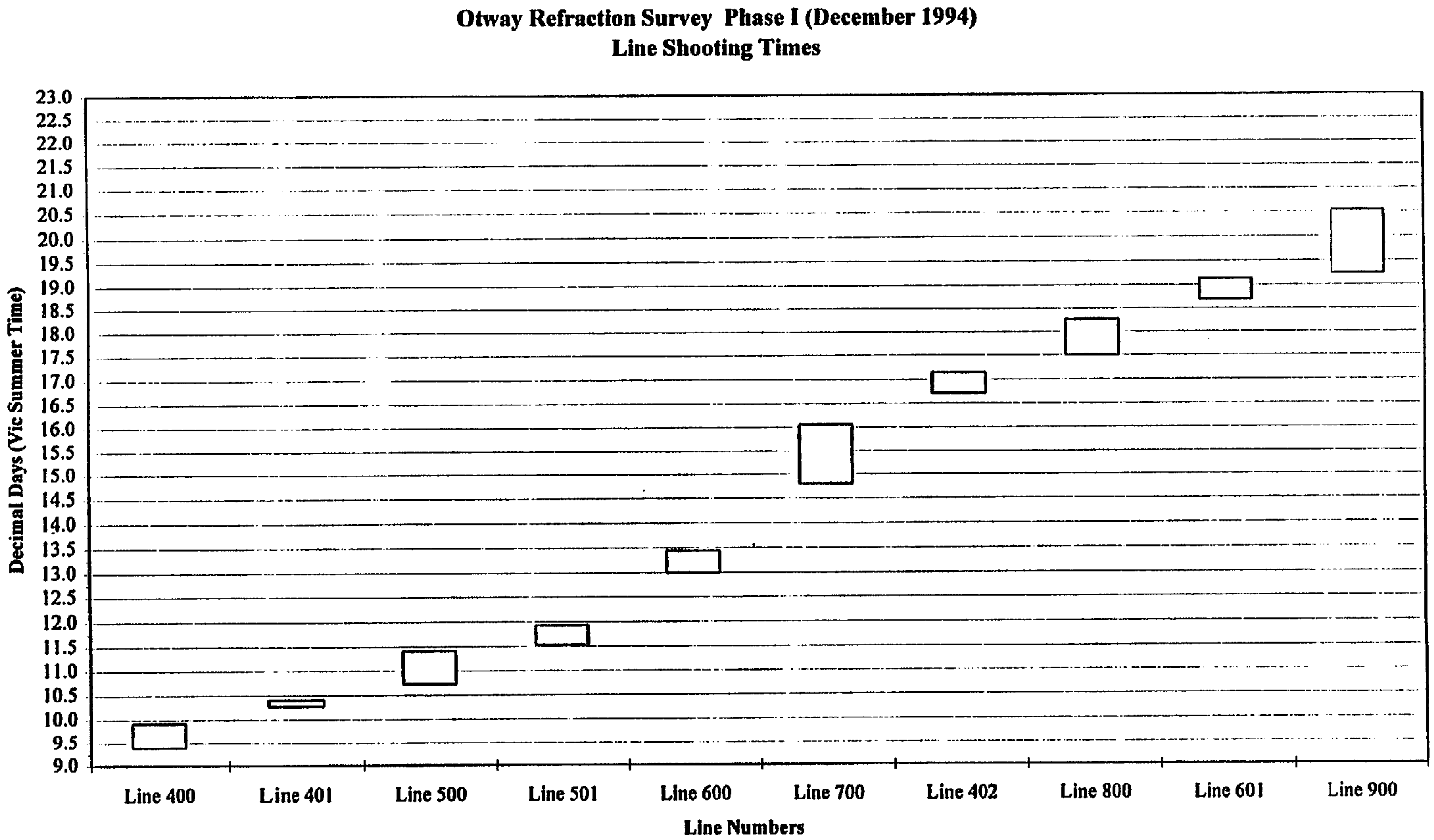


Fig. 14 - Graphical representation of "Rig Seismic" shooting schedule for Survey No. 137.

Otway Refraction Survey Phase II (January 1995)
Line Shooting Times

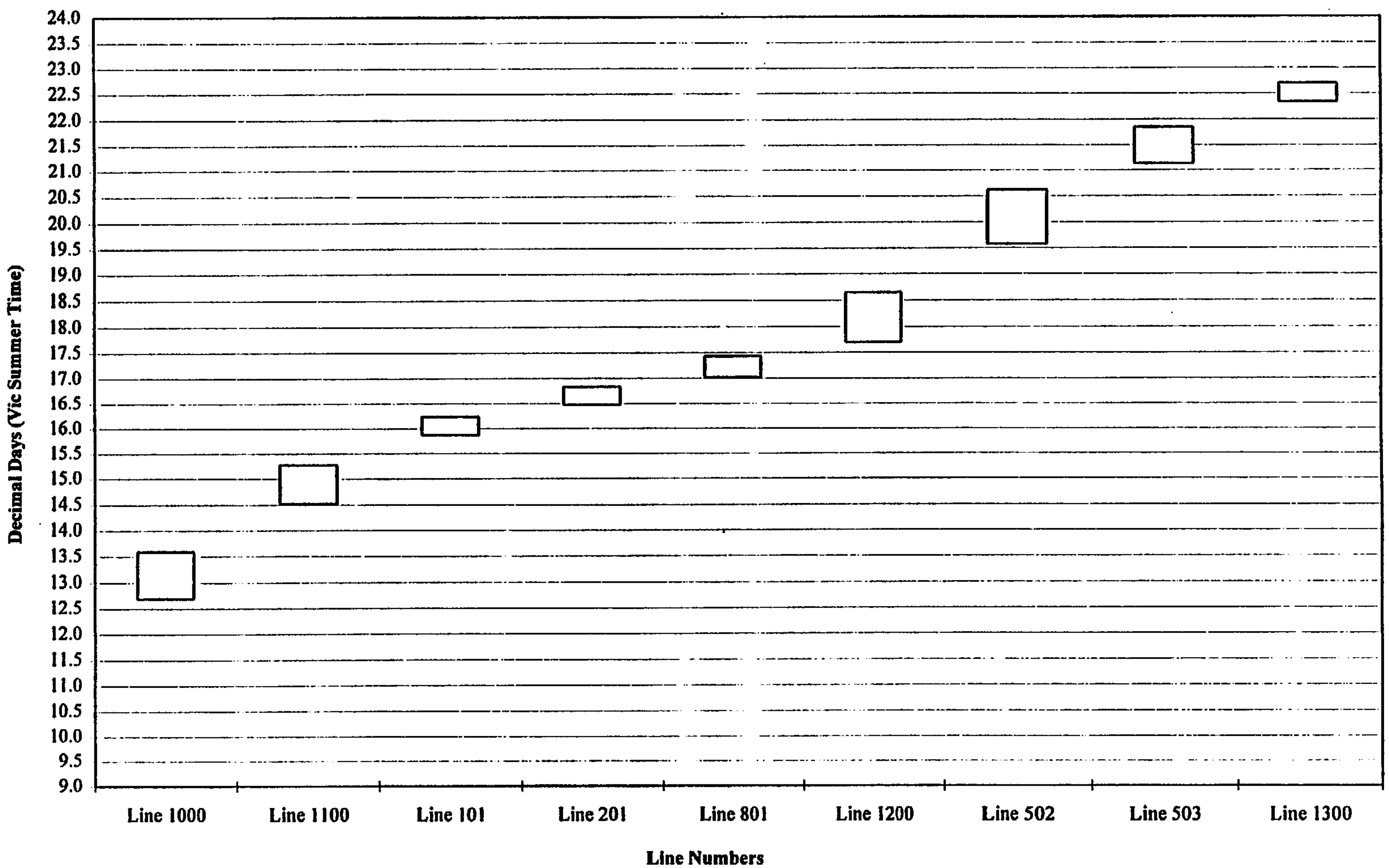


Fig 14 (continued)

Seismic Recording System

Instrument Type:	MUSIC Recording System
Manufacturer:	AGSO
Serial Number:	150964
Total Recorded Channels:	208
Seismic Data Channels:	192
Recorded Aux Channels:	16 per streamer Channels 193-194: Dummy Channels 195-202: Near-field Gun Signatures Channels 203-207: Water-break Phones Channel 208: Dummy
Streamer Front Channel Number:	1
Sample Interval:	2 milliseconds
Low Cut Filter/Slope:	4 Hz at 18 dB/Octave
High Cut Filter/Slope:	180 Hz at 140 dB/Octave
Record Length:	16 seconds
Recording Medium:	High Density Cartridges M2841
Recording Format:	Demultiplexed (modified) SEG-Y
Recording Density/Speed:	37871 bpi 18 Track / 39.37 ips (1000mm/second)
Recording Polarity:	Pressure increase = negative number on tape
External Header Format:	N/A
Max Input RMS:	+/- 7.07 Volts
A/D Linearity:	0.20 %
Accuracy of Gain Ranging:	0.25 %
Channel-Channel Accuracy:	0.40 %
Harmonic Distortion:	0.01 % at 3200mV 31.25 Hz 0.22 % at 1mV 31.25 Hz
Multi-trace Plotter:	Epson DFX-8000 Printer

Table 4 - "Rig Seismic" seismic recording system specifications.

Seismic Streamer

Streamer:	FJORD Instruments Analogue Streamer
Manufacturer:	FJORD Instruments
Number of Streamers:	1
Active Length:	4800 metres
Active Section Length:	100 metres
Number of Active Sections:	48
Active Groups:	192 (configured by in-streamer program plugs)
Hydrophones Per Group:	40
Groups Per Section:	4
Group Length:	25 metres
Group Interval:	25 metres
Hydrophone Sensitivity:	44 V/Bar
Hydrophone Type:	Transformerless Charge Coupled Teledyne T-1
Depth Transducer Type:	N/A (Using cable leveller depths)
Depth Transducer Positions:	N/A (Using cable leveller depths)
Cable Leveller Type:	25 x Syntron RCL-3
Cable Leveller Positions:	Group: 1, 9, 17, 25, 33, 41, 49, 57, 65, 73, 81, 89, 97, 105, 113, 121, 129, 137, 145, 153, 161, 169, 177, 185, head of tail stretch
Cable Compass Type:	5 x Syntron RCU-831 Fluxgate Vector Magnetometer - Externally Mounted
Cable Compass Positions:	Group: 29, 69, 109, 149, 189
Water Break Detectors:	5 x T-1 phones
Water Break Positions:	Group: 1, 49, 97, 145, 189
Towing Depth:	10.0 metres ±1.5 metres (Seq 001 - 021) 13.0 metres ±2.0 metres (Seq 022 - 023)

Table 5 - "Rig Seismic" seismic streamer specifications.

Seismic Source

Source Type:	Single 3000 Cubic Inch Sleeve Airgun Array
Airgun Type:	HGS Sleeve Airgun
Number of Sub-arrays:	2
Number of Guns/Sub-array:	10 Active plus 6 Spare
	Cluster 1: 4 active, 2 spare Cluster 2: 3 active, 2 spare Cluster 3: 2 active, 1 spare Cluster 4: 1 active, 1 spare
Length of Source Array:	13.5 metres
Gun Spacing of Cluster 1:	(G1)-0.5-(G2)-0.5-(G3)-0.5-(G4)-0.5-(G5)-0.5-(G6)
Gun Spacing of Cluster 2:	(G7)-0.5-(G8)-0.5-(G9)-0.5-(G10)-0.5-(G11)
Gun Spacing of Cluster 3:	(G12)-0.5-(G13)-0.5-(G14)
Gun Spacing of Cluster 4:	(G15)-0.5-(G16)
Cluster Spacing:	(1) - 2.5m - (2) - 2.5m - (3) - 2.5m - (4)
Width of Source Array:	15 metres
Subarray Cross-Spacing:	N/A
Nominal Air Pressure:	1800 psi ±10%
Depth Sensors:	4 per subarray
Near Field Phones:	4 per sub-array / 1 per gun cluster
Number of Active Guns:	20 (10 per sub-array)
Number of Spare Guns:	12 (6 per sub-array)
Compressors:	6 x A-300 300 scfm Price Compressors (4 in use, 2 as back-up)
Gun Timing Unit:	AGSO GCM
Timing Variance:	±2.0 millisecond
Shot point Interval:	50.0 metres
Towing Depth:	10.0 metres
Towing Depth Tolerance:	±1.5 metres

Table 6 - "Rig Seismic" seismic source specifications.

Navigation and Positioning

Navigation System:	AGSO DAS - Data Acquisition System	
Data Storage:	Andataco 4320NT Cartridge Drives	
Primary Navigation:	Racal 1 Multifix Version 1.3 Differential Global Positioning System	
Primary Nav Equipment:	Receiver:	Trimble 4000DS
	Demod:	Racal Skyfix Satellite Differential Demodulator 2402
	Medium:	Inmarsat Satellite Dish
	Frequency:	72.475 MHz
	Ref Station:	Melbourne Adelaide Sydney Perth
Secondary Navigation:	Racal 2 Multifix Version 2.0 Differential Global Positioning System	
Secondary Nav Equipment:	Receiver:	Trimble 4000DS
	Demod:	Racal Skyfix Satellite Differential Demodulator 2402
	Medium:	Inmarsat Satellite Dish
	Frequency:	82.475 MHz
	Ref Station:	Melbourne Adelaide Sydney
Tertiary Navigation:	Doppler Sonar / Gyro Dead Reckoning	
Tertiary Nav Equipment:	Magnavox MX 610 / Sperry Mk 37 Gyrocompass	
Additional Navigation Equipment:	Raytheon DSN 450 Doppler Sonar Magnavox MX 100 GPS	
Echo Sounder:	Raytheon CESP III (3.5 kHz and 12 kHz)	
Gravity:	Bodenseewerk Geosystem KSS-31 Marine Gravity Meter	
Magnetics:	Geometrics G801/G803 Magnetometer	
Mode of Shooting:	Single Streamer / Single Source / 2D	
Shot point Interval:	50.0 metres	
Nominal Shooting Speed:	5.5 knots	
Effective Fold:	4800%	

Table 7 - "Rig Seismic" navigation and positioning systems.

Vessel

Name:	R/V RIG SEISMIC
Crew Party Number:	N/A
Radio Call Sign:	VMMR
Owner:	Galerace Limited
Year Built:	1982
Registration:	Research Vessel
Home Port:	Newcastle, New South Wales
Official Number:	851492
Length:	72.5 metres
Beam:	13.8 metres
Draft:	6.0 metres
Gross Tonnage:	1595 tonnes
Nett Tonnage:	421 tonnes
Displacement Tonnage:	3000 tonnes
Main Engines:	Bergen Type Norma KVMB-12 - 2640 HP / 825 rpm
Auxilliary Engines/Generators:	3 x Caterpillar - 564 HP / 482 KVA 1 x Mercedes - 78 HP / 56 KVA 1 x GEC Dynamic Positioning System
Shaft Generator:	AVK 1000 KVA - 440 V / 60 Hz
Side Thrusters:	2 forward, 1 aft, each 600 HP
Cruising Speed:	10 knots
Maximum Speed:	13 knots
Propellers:	1 x Variable Pitch
Gyro Compass:	Sperry Mk 37
Fuel Capacity:	483.55 tonnes
Fresh Water Capacity:	107.98 tonnes
Water Maker:	10 tonnes per day
Endurance:	20,000 nautical miles at 13 knots 13,500 nautical miles at 5 knots

Table 8 - "Rig Seismic"; general specification of vessel.

Contact Numbers:	Inmarsat:	1545120 (Phone / Telex) 1545121 (Fax / Data)
	Mobile:	018 898 200 (Phone) 018 620 515 (Phone) 018 632 656 (Fax)
Radar:	Furuno FAR-2832S 10 cm (ARPA) Furuno FR-2020 3 cm	
Communications:	Inmarsat C Sailor MF Radio 2 x VHF fixed antenna radios 4 x VHF hand-held radios 4 x Motorola UHF hand-held radios Aircraft radio 27 Mhz citizen's band radio Bridge mobile telephone Inmarsat A (2 identification numbers) 3 x General use mobile phones Facsimile	
Helicopter Deck:	Rear-mounted Markings as per AGA 7 General Conditions Suitable for Bell 206B Longranger / Squirrel	
Accommodation:	38 single berth cabins 3 double berth cabins 42 persons total	
Hospital:	1 berth	
Life Boats:	2 x enclosed 40 man motor driven lifeboats	
Life Rafts:	4 x 20 man inflatable 1 x 6 man inflatable	

Table 8 (continued)

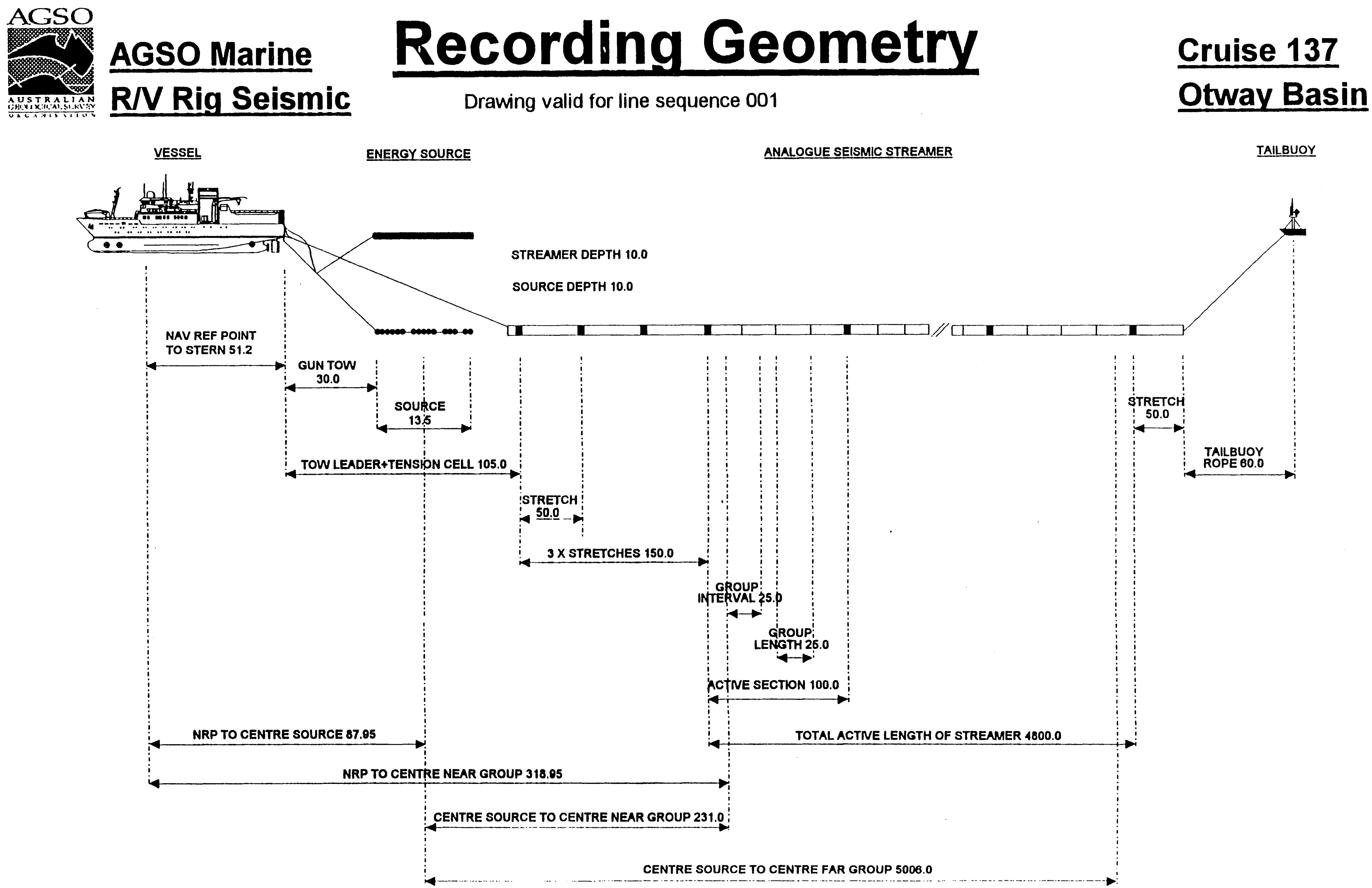


Fig. 15 - Example of "Rig Seismic" recording geometry.

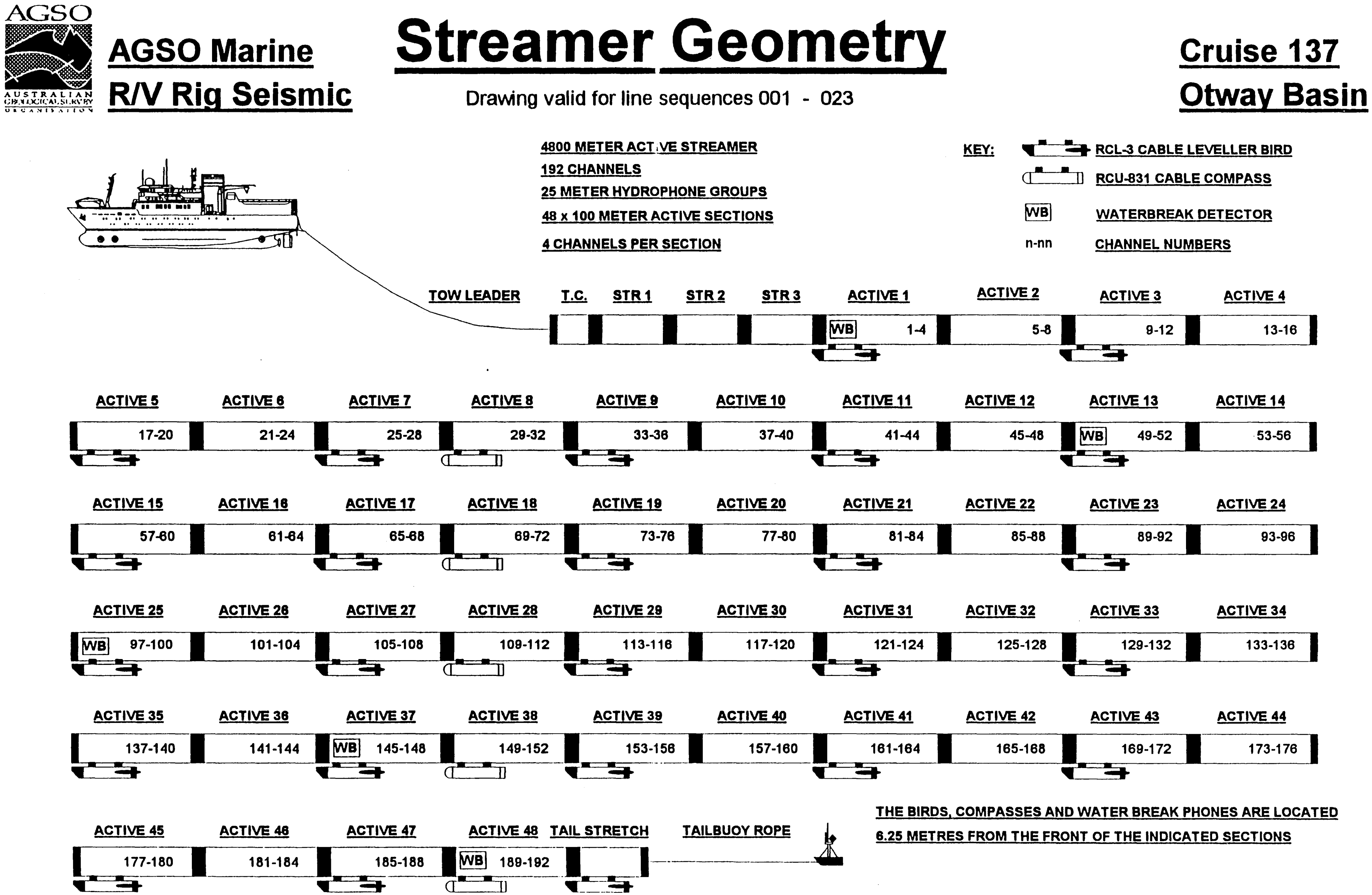


Fig. 16 - Example of "Rig Seismic" streamer geometry.

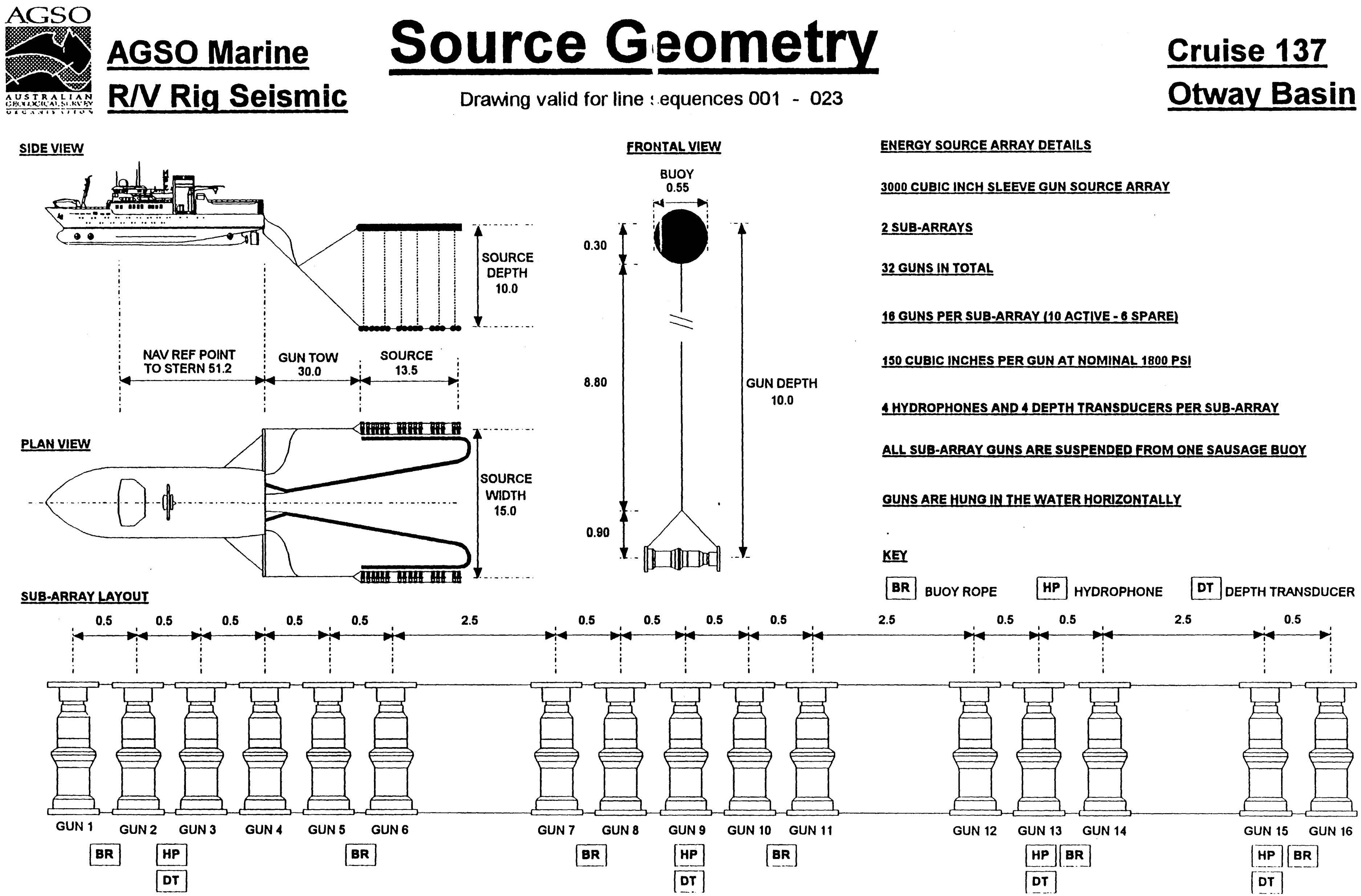


Fig. 17 - Example of "Rig Seismic" source geometry.

APPENDIX 3

EXAMPLES OF SEISMIC DATA FILES

The following pages contain examples of the data files used in the digitising, processing and plotting stages of seismic data, illustrating the formats of the various files.

Examples of Data Files: Line 500 at Station 1 (Milltown)

1. OT500.ASC, Shot Position File

137/000500	100382435.04S1411120.02E99999999	9.99993E+19
137/000500	101382435.37S1411122.14E99999999	9.99993E+19
137/000500	102382435.71S1411124.29E99999999	9.99993E+19
137/000500	103382436.03S1411126.44E99999999	9.99993E+19
137/000500	104382436.39S1411128.57E99999999	9.99993E+19

etc...

2. S137_500.ASC, Shot Time File (UT)

137/000500	100	344	6092266
137/000500	101	344	6094129
137/000500	102	344	6100028
137/000500	103	344	6101905
137/000500	104	344	6103803

etc...

3. 500DIST.XLS, Shot Position File (decimal minutes)

SP	Lat			Lon			Lat	Lon	Lat	Lon
No	Deg	Min	DSec	Deg	Min	DSec	DMin	DMin	DMin	DMin
100	38	24	35.04	141	11	20.02	24.584	11.33367	24.584	11.33367
101	38	24	35.37	141	11	22.14	24.5895	11.369	24.5895	11.369
102	38	24	35.71	141	11	24.29	24.59517	11.40483	24.59517	11.40483
103	38	24	36.03	141	11	26.44	24.6005	11.44067	24.6005	11.44067
104	38	24	36.39	141	11	28.57	24.6065	11.47617	24.6065	11.47617

etc...

4. 500TIME.XLS, Shot Time File (local recorder time)

SP	Time (UT)					Time (UT)	Time (Recorder at Milltown) = DDays (UT) + 11 hrs (Vic Summer Time) - 8 sec (Omega dip switches corr)	Time (Recorder)									
No	Day	Hr	Min	Sec	DSec	DDays		Day	Hr	Min	Sec	DSec	Day	Hr	Min	Sec	DSec
100	10	6	9	22	66	10.25651227	10.71475301	10	17	9	14	66	10	17	9	14	66
101	10	6	9	41	29	10.25672789	10.71496863	10	18	9	33	29	10	17	9	33	29
102	10	6	10	0	28	10.25694769	10.71518843	10	19	9	52	28	10	17	9	52	28
103	10	6	10	19	5	10.25716493	10.71540567	10	17	10	11	5	10	17	10	11	5
104	10	6	10	38	3	10.25738461	10.71562535	10	18	10	30	3	10	17	10	30	3
etc...								etc...									

5. 500DT.TXT, Merged Shot File (position, times)

LINE 0500, STN 1, CRUISE 137

100	38	25	141	11	-99	10	17	9	14	66
101	38	25	141	11	-99	11	17	9	33	29
102	38	25	141	11	-99	12	17	9	52	28
103	38	25	141	11	-99	13	17	10	11	5
104	38	25	141	11	-99	14	17	10	30	3

etc...

6. STAT.DAT, Station Location File

TABLE 1. Location of Onshore Refraction Stations (Otway Dec 94)

1	38	2.3	141	40
2	38	16	141	32
3	38	14	142	14
4	38	2.7	142	14
5	38	32	142	55
6	38	16	143	4.1

7. DI01DT.01T, Shot Distance/Time File (distances, times)

LINE 0500, STN 1, CRUISE 137

100	58.966	225.4	10	17	9	14	66	-99
101	58.937	225.3	10	17	9	33	29	-99
102	58.907	225.3	10	17	9	52	28	-99
103	58.877	225.2	10	17	10	11	5	-99
104	58.848	225.2	10	17	10	30	3	-99

etc...

8. 500MILL.DAT, Shot Distance/Time File (TEST97 format)

LINE 0500, STN 1, CRUISE 137

100	58.966	10170915
101	58.937	10170933
102	58.907	10170952
103	58.877	10171011
104	58.848	10171030

etc...

9. MI500.LST, List File (shot file names)

MI0100.500
MI0101.500
MI0102.500
MI0103.500
MI0104.500
etc...

10. MI500.TIM, Shot Time File

LINE 0500, STN 1, CRUISE 137

100	10	17	9	14	66
101	10	17	9	33	29
102	10	17	9	52	28
103	10	17	10	11	5
104	10	17	10	30	3

etc...

11. DRIFTS.TXT, Station Clock Drift File

1	9.3819	-0.005
1	10.5944	-0.087
1	15.359	0.087
1	19.6653	0.102
1	21.0972	0.18
1	21.3882	0.18
2	9.4597	0.008

etc...

12. ST500.LST, Plot List File (shot file names)

MI0680.500
MI0686.500
MI0692.500
MI0698.500
MI0704.500
etc...

13. ST500.REC, Plotting Parameters File

LINE 500, STATION 1 (MILLTOWN), 11 TR STACK, 5-22Hz, NORM, SP 680-3303
1
5
145
45
8
-1
-1
0
0
MI0680.500
6.157
11
5
22
1
1
etc...

14. ST500.PS, Postscript Graphics File

```
initgraphics
%!PS-Adobe-2.0
%--------------Prolog-----------------
%%Creator:                  MicroGlyph  Systems/SciPlot(TM)  V4.0
%%Title:                    (Plot       Frame)
%%ColorUsage:               Black&White
%%DocumentProcessColors:    Black
%%BoundingBox:              0           0                    576         720
%%Pages:                    0
%%EndComments
/SPdict                     3           dict                 def         %define     local       dictionary
SPdict                      begin       %push                SPdict      onto        dictionary  stack
                            /m          /moveto              load        def
                            /l          /lineto              load        def
                            /s          /stroke              load        def
                            end         %pop                 SPdict      off         dictionary  stack
%%EndProlog
%--------------Script-----------------
%%BeginSetup
%Set                        Default     Page                 Parameters
gsave                       %save       current              graphics    state
SPdict                      begin       %push                dictionary  on          stack,      make     current
                            0.24        0.24                 scale
                            1           setlinewidth         0           setlinecap  0           setlinejoin
                            []          0                    setdash     0           setgray     10       setmiterlimit
%%EndSetup
%Draw                       Plot        Frame
                            newpath
165                         2862        m                    165         2803        l           165      2804     m      174     2804
165                         2803        m                    174         2803        l           165      2802     m      174     2802
174                         2804        l                    165         2803        m           165      2744     l      165     2745
etc...
```

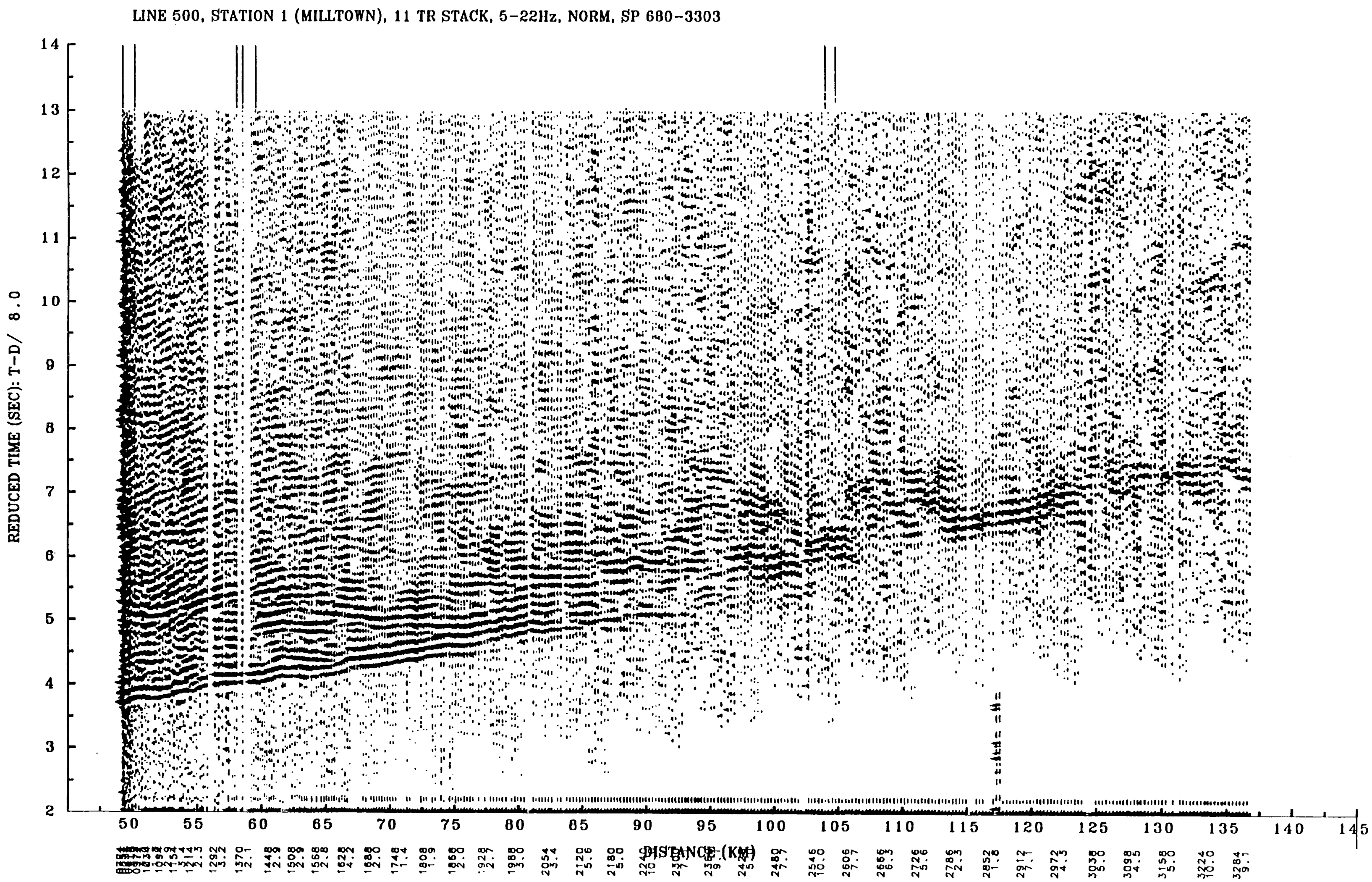


Fig. 18 - Example of a seismic record section from the Milltown site recording airgun shots along Line 500.

APPENDIX 4

"RIG SEISMIC" HGS SLEEVE GUN ARRAY SEISMIC ENERGY SOURCE

This appendix contains general specifications of the Halliburton Geophysical Services (HGS) sleeve gun array used by the "Rig Seismic" during the 1994-95 survey in the Otway Basin. The information is taken from the "Guide to the Marine Data Acquisition System" (N. Johnston, 1995).

The energy source on the "Rig Seismic" is comprised of 32 identical sleeve guns configured as two 16-gun arrays. The arrays are configured in groups of 6, 5, 3, and 2 guns from fore to aft respectively. Each array is normally fired as 4, 3, 2, and 1-gun groups with or without inserts.

Gun type	HGS Sleeve Gun II
Gun volume	150 cu. in. (110 cu. In. with inserts)
Number of guns	20 (in 8 groups) + 12 spares
Volume of total array	3000 cu. In. (2200 cu. in. with inserts)
Air pressure	1800 psi
Gun depth	10 m for deep seismic, 6 m for industry
Overall length of arrays	13.5 metres
Separation of arrays	15 to 25 metres as required

The general geometry of the gun arrays is set out in Figure 19 and the far-field source signature and spectrum are shown in Figure 20.

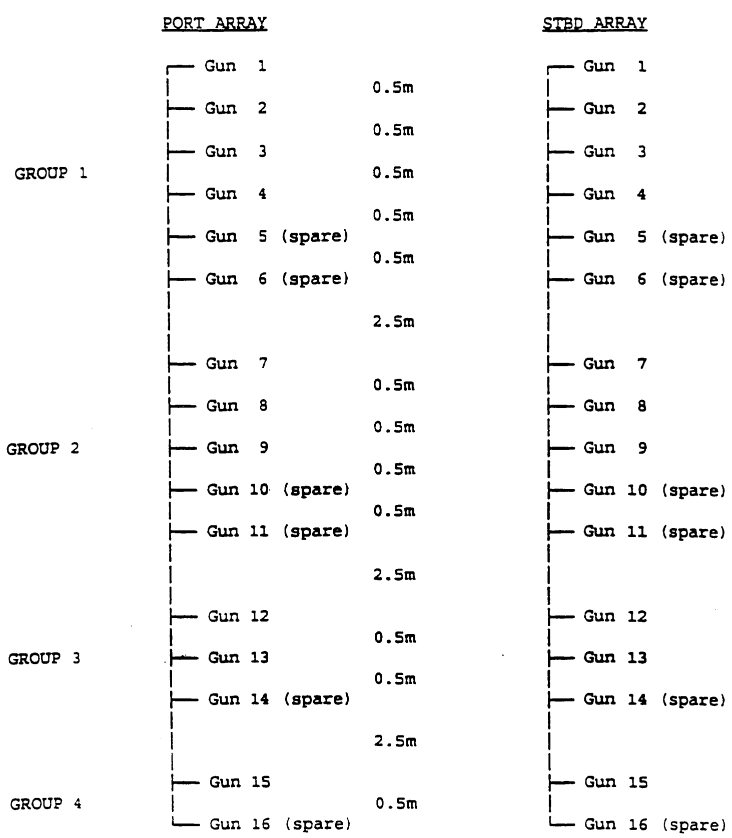


Fig. 19 - "Rig Seismic" sleeve gun array configuration.

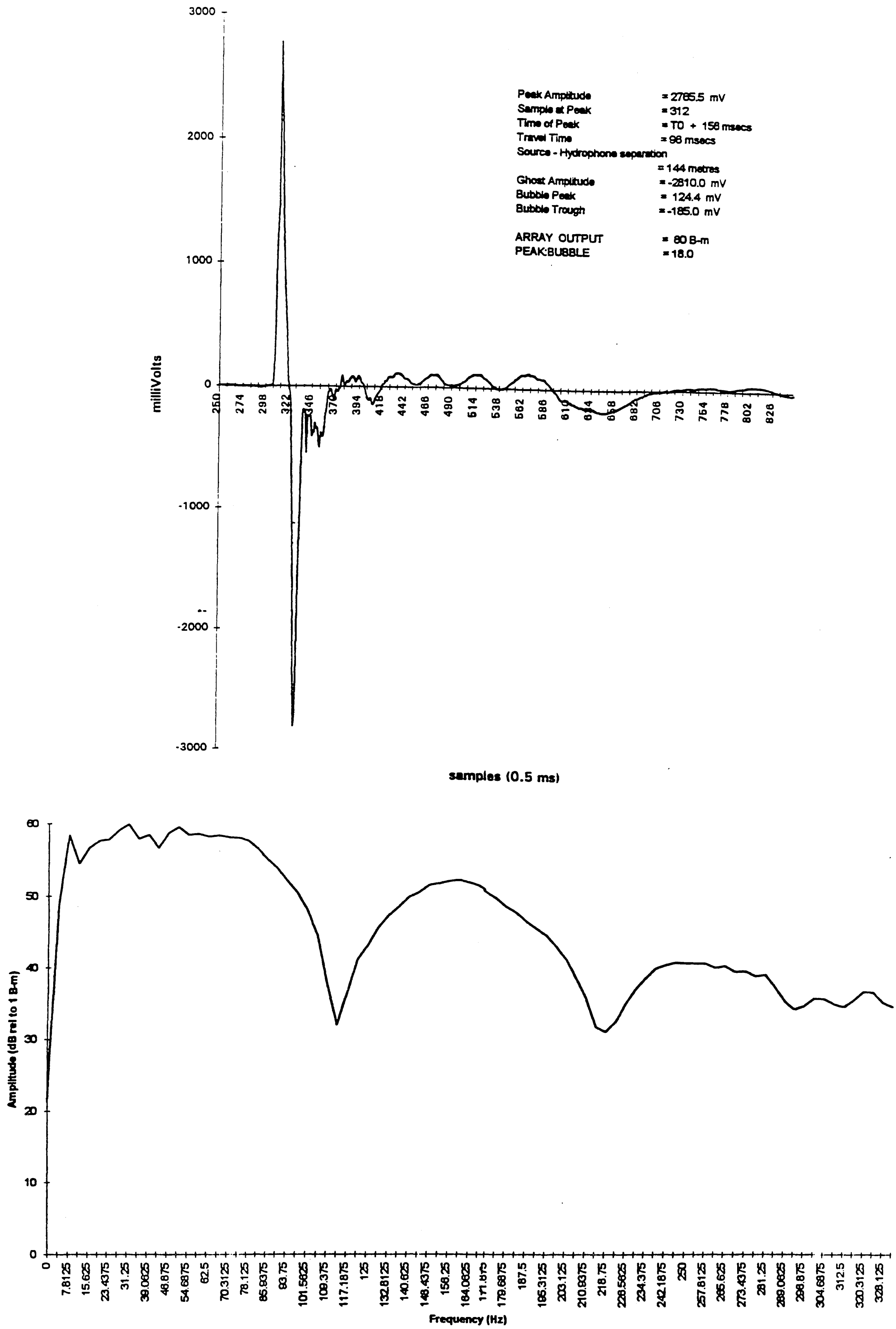


Fig. 20 - Far-field signature and spectrum of sleeve gun array, filters 4-360 hz.

APPENDIX 5

EARTHQUAKE BULLETINS FROM THE AUSTRALIAN SEISMOLOGICAL CENTRE FOR DECEMBER, 1994, AND JANUARY, 1995.

These bulletins list some of the teleseismic earthquakes which may be used to check timing and travel-time residuals at Otway Baisn sites. More comprehensive lists are contained in the US Geological Survey "Preliminary Determination of Epicenters" (PDE) bulletins.

Commonwealth Department of Primary Industries and Energy
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION
Australian Seismological Centre
Monthly Report on Australian Earthquakes
No. 94/12A December 1994

Australian earthquakes ML ≥3

Earthquake activity hotted up in December with epicentres unusually concentrated in Central Australia, the sole exception an event on Cape York Peninsula in far-north Queensland. The earthquake swarm at Myrtle Creek near the coal mining town of Leigh Creek in the mid-north of SA was interesting but caused no damage. The aftershock sequence at Tennant Creek continued unabated.

Date	*Time UTC*	*Lat °S*	*Long °E*	*Depth km*	*ML*	*Place*
2	1942 36.4	23.587	130.133	0	4.2	Lake MacKay NT
3	0855 10.3	19.764	133.831	0	3.0	Tennant Ck NT
5	1946 53.7	30.415	138.040	4	3.0	Myrtle Creek SA
5	1957 14.9	30.371	138.000	0	3.1	Myrtle Creek SA
5	2029 40.2	30.414	138.005	0	3.3	Myrtle Creek SA
5	2049 38.5	30.357	137.952	4	4.0	Myrtle Creek SA
5	2102 39.0	30.412	138.013	5	3.8	Myrtle Creek SA
5	2116 34.4	30.397	137.949	5	3.5	Myrtle Creek SA
7	0532 43.5	30.445	137.988	5	3.0	Myrtle Creek SA
9	1553 14.6	30.427	137.944	4	3.2	Myrtle Creek SA
12	0203 5.5	30.395	137.964	0	3.1	Myrtle Creek SA
22	1024 15.8	19.910	134.041	2	3.8	Tennant Ck NT
24	0818 37.7	11.208	139.311	5	3.5	C York Qld
24	1628 0.4	19.828	133.997	15	3.6	Tennant Ck NT
27	1910 14.2	23.649	130.248	5	3.0	NT/WA Border area

Large or damaging earthquakes worldwide

The death toll was low in December reflecting the lack of earthquakes.

Date	*Time UTC*	*Lat*	*Long*	*Dep*	*Magnitude Mb*	*Msz*	*Region and Comments*
10	161737.3	18.24N	101.26W	33N	6.5		Guerrero Mexico, Mw 6.6 (GS) Mo=1.2*10**19 Nm (PPT). Felt strongly in the Mexico City area.
14	072855.8	9.45S	159.28E	33N	5.7	6.0	Solomon Islands. Mw 6.0 (GS)
15	112022.0	37.06 S	177.22E	33N	5.2	6.4	Off E. Coast Of N. Island N.Z.
28	121923.4	40.44N	143.50E	33N	6.5	7 0	Off east coast of Honshu Japan.Mw 7.7 (GS) 7.7 (HRV). Mo=3.4*10**20 Nm (PPT). Two people were killed and more than 200 injured and damage (VI JMA) in the Hachinohe area. Felt as far as Tokyo. Local tsunami generated with maximum wave heights (peak to trough) recorded: 110 cm. at Miyako, 88cm at Hachinohe, 54 cm. at Ofunato, 10 cm at Choshi Honshu, 48 cm at Urakawa, 36 cm at Hakodate and Kushiro Hokkaido.
28	222357.9?	30.60S	179.45E	33N	5.5	6.0	Kermadec Is Region. Mw 5.8

Eastern Standard Time (EST) = Universal Coordinated Time (UTC) + 10 hours
Further Information from:

Australian Seismological Centre: (Canberra) ph: 06 249 9675 fax: 06 249 9969
(Mundaring) ph: 09 295 1555 fax: 09 295 2433

Commonwealth of Australia
Department of Primary Industries and Energy
Australian Geological Survey Organisation

AUSTRALIAN SEISMOLOGICAL CENTRE

Monthly Report on Australian Earthquakes

No. 95/01A January 1995

Australian Earthquakes ML > 2.9

Earthquake activity continued at a high level this month. Most of the events were in the Central Australian region, similar to last month. The Myrtle Creek swarm activity has died down with only one event above ML 3. The aftershock sequence at Tennant Creek continued.

Day	UTC h m s	Lat S	Long E	Depth km	Magnitude	Locality
01	12 27 54.2	28.51	136.17	0	3.2 ML	Oodnadatta SA
02	23 08 22.5	19.69	133.81	8	4.2 ML	Tennant Ck. NT
03	06 33 16.6	13.87	131.27	5	4.1 ML	Katherine NT
09	05 33 57.5	21.05	120.67	5	3.5 ML	Marble Bar WA
11	07 11 37.8	38.18	146.00	8	3.1 ML	Warragul Vic
20	08 04 49.4	20.89	120.78	5	3.2 ML	Shay Gap WA
23	17 44 53.1	30.41	138.01	5	3.2 ML	Myrtle Creek SA
24	08 26 00.4	19.87	134.16	12	3.2 ML	Tennant Ck. NT
27	19 14 34.3	18.86	123.23	5	3.4 ML	Broome WA
28	05 36 16.2	19.86	134.13	8	3.3 ML	Tennant Ck. NT
31	08 45 10.8	28.86	136.45	5	3.0 ML	Lake Eyre SA

Large or damaging worldwide earthquakes This was a very active month, with extensive damage and a large death toll in Kobe Japan and damage and deaths in Colombia. The Banda Sea event on 19 was felt in Darwin.

Day	UTC h m s	Lat	Long	Depth km	Magnitude mB	Ms	Remarks
01	065958.1	40.674N	143.537E	33	5.6	6.2	Mw 6.4 OFF EAST COAST OF HONSHU JAPAN. Felt (II JMA) at Hachinohe.
03	161159.4	57.698S	65.791W	33	6.0	5.6	Mw 6.1 DRAKE PASSAGE. Felt in the Cape Horn
06	223735.2	40.246N	142.242E	33	6.6	6.9	Mw 7.0 NEAR EAST COAST OF HONSHU JAPAN At least 20 people injured in the Hachinohe area and about 5 000 homes lost water and sewer services in the area. Felt from Kushiro Hokkaido to Sendai Honshu.
07	023607.3	40.293N	142.442E	33	6.2	5.6	Mw 6.1 NEAR EAST COAST OF HONSHU. JAPAN
12	102646.7	44.004N	147.051E	33	6.1	5.4	Mw 6.1 KURIL ISLANDS. Felt (IV JMA) on Kozu-shima and (II JMA) on Miyake-jima Felt at Davenport and Santa Cruz.
16	181449.4	51.225N	179.187E	33	5.5	6.0	Mw 6.1 RAT ISLANDS ALEUTIAN ISLANDS.

16	204651.0	34.527N	135.005E	16	6.3	6.9	Mw 6.8 NEAR S. COAST OF WESTERN HONSHU. Over 5000 people killed nearly 26000 injured and extensive damage (VI JMA) in the Kobe and Awaji-shima areas. Over 90 per cent of the casualties occurred along the southern coast of Honshu between Kobe and Nishinomiya. At least 28 people were killed by a landslide at Nishinomiya. Nearly 300 000 people were evacuated to . temporary shelters. Over 50 000 buildings were damaged or destroyed. Numerous fires gas and water main breaks and power outages occurred in the epicentral area. Felt (V JMA) at Hikone Kyoto and Toyooka; (IV JMA) at Nara Okayama Osaka and Wakayam Also felt (IV JMA) at Takamatsu Shikoku. Surface faulting was observed for 9 kilometers with horizontal displacement of 1.2 to 1.5 meters in the northern part of Awaji-shima. Liquefaction also occurred in the epicentral region.
19	095534.2	7.436S	128.329E	170	5.7		Mw 6.1 BANDA SEA Felt MM IV Darwin.
19	150503.6	5.114N	72.914W	18	6.4	6.5	Mw 6.5 COLOMBIA Five people were killed several injured and at least 20 major buildings damaged in the Bogot area. One person was also killed at Manizales an another at Miraflores. More than 500 houses were damaged or destroyed in Boyaca Department; 12 others were destroyed in Casanare Department. Landslides blocked several rivers and streams in Colombia. Felt throughout much of Colombia anc western Venezuela as far as Caracas Venezuela. Two events about 1.5 seconds apart.
21	073024.8	2.440N	126.974E	65	6.0	6.1	Mw 6.2 NORTHERN MOLUCCA SEA. Felt (III) at Manado Indonesia.
21	084729.7	43.283N	146.714E	65	6.6		Mw 6.4 KURIL ISLANDS. Felt (IV JMA) at Kushiro and (III JMA) at Nemuro Japan.
24	041426.2	27.580N	55.634E	33	4.9		SOUTHERN IRAN. Five people injured and some damage in the Fin area.
24	223635.5	5.915S	154.458E	33	5.7	6.2	Mw 6.2 SOLOMON ISLANDS.
27	201653.0	4.587S	134.547E	33	6.1	6.9	Mw 6.7 IRIAN JAYA REGION INDONESIA.
29	031122.6	47.388N	122.365W	17	5.0	4.5	WASHINGTON. Minor damage at the SeaTac Mall. Felt strongly in the Seattle-Tacoma area. Felt from Vancouver British Columbia to Portland Oregon and as far east as Grand Coulee Washington.
29	041657.4	39.985N	40.994E	33N	4.8	4.9	TURKEY. Fifty-eight houses damaged in the Askale area. Felt in the Pulumur and Tercan area.

Eastern Standard Time (EST) = Universal Time + 10 hours
Eastern Summer Time (ESST) = Universal Time + 11 hours
Central Standard Time (CST) = Universal Time + 9.5 hours
Western Standard Time (WST) = Universal Time + 8 hours
Mw = Scalar seismic moment magnitude

ML = Richter magnitude
Ms = Surface wave magnitude
mB = Body wave magnitude
MM = Modified Mercalli Intensity

Further information may be obtained by contacting:-
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