COMADA ENERGY LIMITED
THE PETROLEUM POTENTIAL
OF THE ONSHORE BONAPARTE BASIN
April 1990
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The late Devonian and early Carboniferous sediments of the onshore Bonaparte Basin have attracted petroleum exploration interest over the last 30 years. During this time, however, only eight exploration wells have been drilled in an area of approximately 16,000 square kilometres. Seven of these encountered some form of oil or gas show, and four were sub economic to marginally economic gas discoveries. Over the same period there were a number of phases of mineral exploration around the basin margin for "Mississippi Valley" type base metal mineralization. Many mineral boreholes encountered bitumen shows at shallow depth.

Despite this activity, an unambiguous geological model for the basin has not emerged. This report attempts to briefly trace the evolution of the currently accepted geological ideas, and to address the more relevant of the resulting stratigraphic and structural problems. The prospectivity of the basin is then reviewed, petroleum plays are categorized, and a number of new play concepts are developed. Some of these are conditional on the resolution of specific stratigraphic ambiguities. The final section of this report is an inventory and synopsis of all prospects, leads, and areas of interest arising from the plays categorized in this report. The area of retention licence RL1 has been excluded from this treatment.

This report has been developed on the basis of an in depth examination of all relevant petroleum exploration reports including: well completion reports, geophysical reports, seismic sections and interpretations carried out by the author and by others, geological survey reports and other publications including biostratigraphical works, field mapping by the author in 1986 and 1989 with associated air photo and enhanced thematic mapper interpretation. Partial access to mineral exploration reports and to physical examination of mineral exploration cores was also available courtesy of BHP Minerals.

INTRODUCTION
REVIEW AND DISCUSSION

The feature that first directed attention to the onshore Bonaparte Basin was the presence of a continuous outcrop of Devonian or Carboniferous limestone (later termed the Ningbing Limestone) extending over some 70km of strike and up to 7km width. This clearly marked the western margin of a marine basin, an entity with which onshore Australia is poorly endowed. At this time marine basins were considered to be the only source areas for substantial oil accumulations. Similar Carboniferous carbonates were known at the basin's south eastern margin. The first exploration well in the basin was drilled at this margin and encountered minor, but encouraging, oil shows. This was Spirit Hill -1, drilled in 1960 to 915 metres.

Bonaparte -1, the first deep test, was located on the basis of gravity and extremely poor seismic data as a structural test about 15km east of the western margin. This well was drilled in 1963 to a TD of 3209 metres. After spudding in early Permian sands and conglomerates, and penetrating late Carboniferous sands and carbonates in the shallow section, the well entered a long sequence of silty and very fine sandy shales and remained in this lithotype with little variation to TD. Occasional tight sands from 1500 metres to TD had gas shows. It was fairly reasonably concluded that this well had penetrated a basinal equivalent of the carbonates exposed at the margin, and indeed some biostratigraphical evidence supported this idea. The simple model of a carbonate "reef complex" passing rapidly eastward into a basinal "shale" province has persisted to the present day, but it is worth re-examining the basis for this model, as this involves consideration of the problems inherent in studying the basin margin in general.

Le Blanc (1964) suggested that the lowermost sandy beds in Bonaparte -1 might be of Frasnian age, ie. equivalent to the section beneath the "Ningbing Limestone", although no macro or microfossils were recovered from the lower section. This suggestion was adopted in a number of subsequent industry and published reports, although Mory and Beere (1988) seem to equivocate by indicating TD. for Bonaparte -1 in the Famennian on a graphical section and referring to a basinal facies of the Cockatoo Formation (Frasnian) in the text. We can at least say that there is absolutely no fossil evidence indicating that Bonaparte -1 reached Frasnian section.
So what is the evidence that it reached Famennian sediments? This rests on the identification of one pelecypod *Buchiola* sp. with a known range to the latest Devonian, at 2533 metres in the well. This is not proof positive that the well reached Devonian sediments but must be weighed in the balance. It cannot be demonstrated that *Buchiola* sp. does not range into the early Carboniferous. The specimen could be also be reworked. Conchostracans (a brackish water fauna) at 2699 metres were considered to be washed in (Veevers and Roberts, 1968) as they were associated with pelecypods and trilobites. They were also incompatible with the concept of a deep water basinal shale province. In fact there appears to be no unequivocal evidence of water depth. The basinal sediments are dominated by silty shales and occasional argillaceous sandstones. Source rock analyses commonly indicate a predominance "woody" or terrestrially derived material. This combination could well result from rapid shallow marine deposition rather than indicating a deep water environment off a carbonate shelf.

However, the model of a narrow, and reefal, carbonate shelf passing rapidly out into basinal sediments became firmly established in the mid 60's following the work in particular of Playford in the Canning Basin and Veevers in the Bonaparte Basin. Playford was developing his concept of a Devonian "Great Barrier Reef" in the Canning Basin. (see Playford 1980). and both Playford and Veevers appear to have regarded the "Ningbing Limestone" as an analogous situation. Veevers mapped the "Ningbing Limestone" along with much of the onshore Bonaparte Basin. He described the "Ningbing Limestone" as a reef complex and differentiated backreef, reef, and forereef facies. Most importantly, datings from his collections suggested that the carbonate deposition of the reef complex spanned the whole of the Famennian and continued into the Tournaisian.

Veevers and Roberts, (1968) describe a western platform carbonate province, a northern basinal shale province extending well into the NT., and an eastern platform conglomeratic province with the platforms merging to the south. The results of Aquitaine's Keep River -1 well were not available to Veevers at this time. This well, spudded in 1968, was drilled to 4762 metres, and penetrated over 1000 metres of platform carbonate considered to be a Ningbing Limestone equivalent, before reaching TD in probable sandstone of the Cockatoo Group. This intersection reduced the area of the supposed basinal shale province, as illustrated in the amended palaeogeographic reconstructions in Roberts and Veevers (1973). To their credit, Veevers and Roberts (1968) did indicate the possibility of a Famennian carbonate province extending to the north east from the Pincombe Inlier.

In summary then, Bonaparte -1 lies between: 15 km to the west an outcrop area probably representing about 1000 metres of Famennian to Tournaisian carbonate, and 40 km to the east an intersection of around 1000 metres of Famennian to Tournaisian carbonate in the Keep River -1 well. The only dating of the relevant section in Bonaparte -1 is a relatively non specific determination which, if accepted, could be as young as uppermost Devonian. Did then Bonaparte -1 penetrate section equivalent to the whole or to part
of the carbonate complex or did it reach TD. above the carbonate section?

The hydrocarbon plays presented later in this discussion do not stand or fall on the presence or absence of an offshore clastic equivalent of the "Ningbing Limestone". The critical point being made is that the basic evidence for the existing basin model is at best ambiguous. Three possible basin settings for Bonaparte -1 are illustrated opposite. Diagram 1 (Model 1) represents conventional wisdom, i.e. the entire Upper Devonian including the platform carbonates and at least part of the Cockatoo Group passes eastward into a basinal shale facies. Diagram 3 shows the extreme alternative possibility with no major Upper Devonian or Tournaisian east - west facies change. Diagram 2 represents one of a multitude of intermediate possibilities with only the uppermost Devonian and Tournaisian changing from carbonate to fine clastics towards the east.

The major implication of the three models is that they differ with respect to the timing of the onset of the development of the Carboniferous basin. Model 3 implies an Upper Devonian to Tournaisian shelf of greater extent than the Carboniferous basin and possibly having no geometric relationship with the Carboniferous basin. Model 2 suggests that the tectonic movements which determined the geometry of the Carboniferous basin commenced in the mid Famennian, and the conventional model 1 requires the basin geometry to be initiated in Frasnian time or earlier.

Unfortunately, even the most recent seismic acquired in the Bonaparte area is of extremely poor quality. It is impossible to tie outcrop to the well, or indeed, even to tie to areas of better data quality. All that can be said is that the dip on the basin margin is sufficiently steep to place the top of any mid Famennian carbonates or equivalents below TD. in the well, as required by models 2 and 3.

Bonaparte -2 was drilled in 1964 to a TD of 2136 metres. This well was located some 8 km from Bonaparte -1 in an updip location closer to the basin margin. A gas flow of 1.54 MMCFD was tested from a Milligans Formation sand at 1439 metres.

After a break in exploration in the basin of about 10 years Australian Aquitaine Petroleum drilled three wells; Weaber -1 (1982) to 1950 metres, Ningbing -1 (1982) to 1269 metres and Skull -1 (1984) to 2000 metres. The Famennian carbonates were the targets for all three wells and Ningbing -1 in particular was located to test a small seismic anomaly thought to represent a reefal build up. Ningbing -1 encountered a good live oil show (cored) in fractured and vughular micritic limestone with no effective permeability. Weaber -1 had no shows in the tight carbonates it penetrated and was abandoned. This well was later re-entered by Santos Limited and tested as a potentially commercial gas discovery from the Tournaisian "Bnga Sandstone". Skull was targeted on a strong reflector on a "Flower structure" which proved to originate from a high velocity sandstone (Visean?). This well was abandoned probably well short of its target carbonates and encountered only minor gas shows.
DIAGRAMMATIC SECTION

FIGURE 3.
Aquitaine had strongly adopted the "Playfordian" reef margin model for the basin. Like the results of Bonaparte, the actual evidence for a basin fringing reef, or a reef prone basin margin deserves some scrutiny. Vevers & Roberts (1968) describe a number of occurrences of "reef" in outcrop. e.g. "The reef consists of massive algal (Renalcis) limestone, 'reef tufa', stromatolitic limestone, Stromatactis limestone, and much recrystallized limestone and dolomite." It must be stressed that the localities described as reef make up only a very minor proportion of the carbonate outcrop area. It can also be noted that Renalcis and stromatolitic limestone are now considered to be very minor constituents of these localities. By far the most common facies represented is the well bedded "back-reef". Later workers advisably prefer the term "platform carbonate" for these rocks. Vevers & Roberts (1968) also recognized a number of "fore-reef" localities but in only one case could they claim that the "fore-reef" was directly associated with "reef". These localities are now more safely described as "marginal slope facies". Certainly the outcrop pattern mapped by Vevers was not that of an extended carbonate platform with a reefal margin extending along the strike length of the Ningbing Limestone" outcrop. However, this seems to have been the model implicit in the exploration carried out by Aquitaine, influenced strongly no doubt by the conventional wisdom regarding the Canning Basin which prevailed at that time.

Whilst it is not unreasonable to expect to find reefal builds-ups on an extensive carbonate platform, considerable attention must be given to the structure and the structural setting of the outcrop before it can be concluded that the outcrop edge delineates a long standing platform margin. Structuring in the Ningbing Range was mapped by Gausden (1986) for the Moonie Oil Company. It was argued in this report that the easterly dips of 10° to 30° that are almost ubiquitous along the eastern (basinward) front of the Ningbing Range were most unlikely to be depositional - a key element of the "Playfordian" model - particularly in those areas where platform carbonates with algal mats and bedded stylolites were dipping strongly basinwards. It was also suggested that the major distinguishing features of the "reef" localities, i.e. massive, recrystallized, caverned, could equally be the result of deformational processes. This idea echoes to some extent the almost heretical paper by Logan and Semeniuk (1976) which attributes the key elements of the reef margin model for the Canning Basin to the processes of dynamic metamorphism. Logan (1984) is also an informative work on the pressure responses in carbonates in the Canning Basin and an introductory paragraph is worth quoting as it appears to be equally applicable to the Bonaparte Basin. "Exploration for carbonate targets in the Canning Basin has been mostly based on sedimentary facies models with the term "reef" as a key word. This approach has not been particularly successful and the models provide little guidance to prediction of porosity and permeability in prospects defined by seismic techniques and/or by drilling. Deformational features in the rocks mostly have been ignored or erroneously interpreted as sedimentary or early diagenetic. This is something of a paradox because there is fairly general consensus that the Canning Basin has been a region of large-scale and relatively intense tectonism throughout its history. Is it possible that this tectonism has not affected the sequences within this basin."
Once again we are presented with two extremely different models. A reef/facies model = model 1 - conventional wisdom - and a tectonic/deformation model = model 3 - extreme alternative. Is there a compromise model 2? Perhaps surprisingly there is. If we envisage a number of growth fault zones, with or without a shearing component, and if structural movement commences during deposition of the carbonate complex and continues to a much later time, then we might expect any reefal build-ups to develop preferentially on the high side of such fault zones. Depending on relative movements of individual fault blocks, a reef talus might be expected to develop, or alternatively a tectonic breccia, or as a further alternative, a depositional breccia resulting from platform destruction. In more general terms, if it is accepted that the reef/facies model can only be applied to far thinner time slices and more limited spatial areas than the authors of this view generally present, then there is little problem in the resolution of the apparent reef/deformation conflict. However, once the reef/facies model is abandoned in its general form, then the stratigraphy of the critical late Devonian and early Carboniferous times is thrown open to review.

The only exploration well to investigate the western basin margin to date has been Ningbing -1. This well penetrated 203 metres of limestone from 1012 to 1215 metres beneath Visian aged Milligans Formation. The well reached TD. at 1269 metres in a fine to medium grained quartz sandstone, which was porous and permeable in part, and had traces of residual oil saturation. The limestone was dated as early Famennian, on the basis of a single conodont specimen (P. Glabra Pectinata) from the core at 1022 metres. Conodont determinations from cuttings samples over the limestone interval suggested an early Carboniferous age but this result was rejected as contamination in favour of the more reliable core sample. As a result the limestone was considered to represent the lower portion of the "Ningbing Limestone" (early Famennian Djilirri Limestone or Kamilili Formation) and the underlying sandstone to belong to the Frasnian Cockatoo Group (nominally the Cecil Sandstone). We are here presented with an intriguing ambiguity, (or perhaps an expensive error, if the prognosis for the 1988 Garimala -1 well, drilled by Santos Limited, is taken into account).

The problem with this age determination for the limestone in Ningbing-1 is that it is thought that the thickness of carbonate in the adjacent outcrop may approach 1000 metres. It is thus necessary to thin this 1000 metre section of carbonate in a basinward direction to 200 metres without the missing section being represented by sediments of an equivalent age. The proponents of an age equivalent basinal shale province based on the section in Bonaparte -1 cannot have it both ways. Some inkling that something may be amiss is suggested by the literary gymnastics of Mory and Beere (1988) in attempting to explain this situation. "In Ningbing- 1, the apparent lack of middle and late Famennian units is difficult to explain as being due to either erosion or non-deposition, since nearly 500 m of middle to late Famennian sediments are preserved near the basin margin (in Ningbing Range). Possibly the Ningbing-1 area was a starved basin, in the middle and late Famennian, with a relatively thin sequence of basinal sediment deposited away from the basin margin. Such a sequence would be predominantly shaly and would be more easily eroded than the calcareous facies, near the basin margin, during
the late Tournaisian regression." Mory and Beere do not comment on the apparent absence of sediments of Tournaisian age in this well.

If Ningbing -1 did indeed reach the Frasnian then any explanatory model must see the strongly basinward dipping reflector, represented by limestone at 1000 metres in the well, as an erosional top of the carbonate complex. The internal structure of the complex must also be relatively flat dipping, or even back dipping, in order to achieve the required erosion of the later Famennian. This scenario implies that considerable uplift and erosion took place in the Tournaisian prior to rapid subsidence and deposition and onlap of the early Visean shales. Before erecting this history it is at least prudent to examine the strength of the biostratigraphy of the section in Ningbing -1.

In the first place, basing a key dating on a single specimen must be regarded as perilous. The specimen may be reworked, misidentified, or even not as time specific as presently thought. Against these suggestions, Nicol (pers. com.) indicates that the preservation of the specimen is too fine to be reworked, is confident of the identification, and is confident of the zonation which also has no Palmatolepid ranging younger than the late Devonian. However, Mory and Beere (1988) report considerable reworking of earlier conodont forms in late Famennian portions of the Ningbing Group. In addition, by cross referencing the early collections of Vevers as determined by Druce (1969) with the outcrop mapping of Mory and Beere, it appears that P. glabra Pectinata occurs in units of the later portion of the carbonate complex. Again reworking may be suspected and in this respect it should be noted that many of the younger carbonate units are either obvious limestone breccias or contain breccia "ghosts". Destruction of the whole sample for conodont determination means that the matrix and the possibly much older breccia fragment cannot be differentiated. A "reworked" conodont from the breccia may thus still be finely preserved.

An even greater conflict arises when a palynological report by G Playford on side wall cores from Ningbing -1 is examined. The lowermost core with recognizable forms is SWC 2 at 1042 metres, that is 20 metres below the key conodont determination. Playford considered the assemblage in SWC 2 to be early Visean. If this evidence is combined with both the evidence of early carboniferous conodonts in the cuttings, and the difficult geological history that must be postulated if the limestone is early Famennian, then the scales are strongly weighted in favour of the limestone in Ningbing -1 being of Tournaisian or early Visean age. The SWC may of course have been contaminated with wall cake. Strangely enough the SWC determination received no comment in the text of the Ningbing -1 WCR. It can be noted that the well had certainly reached its seismic objective. It was also a relatively expensive well and the operator would have been understandably reluctant to extend it below mapped seismic closure. However, if this limestone, with its good live oil show, together with the underlying porous sandstone are in fact of late Tournaisian age, then the prospectivity of this basin margin setting is greatly enhanced.

It has always been an article of faith that Tournaisian age sediments of the "Keep River Group", now termed the Langfield
Group, were not present along the western "Ningbing" margin of the basin. This is despite some fragmentary outcrop evidence of their presence. If the limestone and underlying sandstone in Ningbing -1 are of Tournaisian age then they must be assigned to the Langfield Group. The Septimus Limestone is of late Tournaisian age and would be reasonably consistent with the palynological dating of the Ningbing -1 limestone. The Langfield Group is defined from the eastern or Northern Territory portion of the basin, where approximately 1000 metres of Langfield Group sediment is present in the Burt Range Syncline. The formation underlying the Septimus Limestone in the Burt Range area is the Enga Sandstone. It is thus reasonable to assign the sandstone at TD. in Ningbing -1 provisionally to this unit if the palynological dating is accepted.

We are thus confronted with two quite different stratigraphic interpretations which again lead to two possible extreme models for the basin margin. "Compromise" models which would see the limestone intersection as late Famennian or early Tournaisian could also be developed. Although no firm conclusions can be drawn from the point, it is interesting to note that the prognosis for the 1988 well, Garimala -1, was derived from a "model 1" tie to Ningbing -1. Garimala -1 was expected to reach TD. in Frasnian sands but was instead abandoned at PTD. in sediments no older than late Famennian (and probably younger).

To add to the already dire stratigraphic confusion, towards the northern end of the Ningbing Range, another limestone unit, the Utting Calcarenite, abuts the Famennian carbonates in outcrop. This was considered to be of lowermost Visean age on the basis of conodonts (Druce 1969) and early Visean from brachiopods (Thomas 1962). Mory and Beere (1988) on the other hand suggest a late Visean age on the basis of foraminifera and on stratigraphic relationships. They place the Utting Calcarenite at the top of the Milligans Formation, but the evidence for this placement is dubious and appears on the assignment of a 30 metre shale interval in mineral borehole WBNS005 to the Milligans Formation. The overall problem of course is the convergence of a number of unconformities towards the basin margin making it impossible to reliably extrapolate any given outcrop datum back into the basin. The same problem bedevils any attempt to carry seismic reflectors up to outcrop. All we can reasonably say with regard to the Utting calcarenite is that the conodont age is tantalizingly similar to that of the palynological age for the limestone in Ningbing -1, thus the Utting Calcarenite could be the uppermost unit of the Langfield Group at the western basin margin. A possibly mildly diachronous relationship between the Utting Calcarenite, the Ningbing -1 limestone, and the Septimus Limestone is thus implied.

Following the failure of Skull -1, and with interest in the area waning, Aquitaine withdrew from EP126 and operatorship passed to Alliance Oil Development, and then in fairly quick succession to The Moonie Oil Company and then to Santos. There was thus little continuity in exploration philosophy for the basin. Santos followed up the Weaber -1 "rediscovery" with Weaber -2 and 2A. Weaber -2A proved to be on the downthrown side of a fault and the target sands were low and shaled out. They then drilled the above mentioned Garimala -1 which had some interesting oil shows in the
shallow early Carboniferous section and also tested gas at 470,000 CFD from a Tournaisian? sand.

Santos did achieve a marked improvement in the quality of the seismic in the basin, particularly in the basin margin areas. Some improvement of older seismic was also achieved through reprocessing. During 1989 all partners except for Comada Energy Limited elected to withdraw from both EP 126 and the then OP 186. Santos, in conjunction with Comada, applied for and was granted a retention license (RL1) of 5 graticular blocks covering the Weaber Field and the Keep River area. After statutory relinquishments, Comada was granted a renewal of EP 126 and of EP 31 which replaced OP 186.
**PROSPECTIVITY**

Gas and oil have been generated in the onshore Bonaparte Basin. Sub-economic gas discoveries have already been made in both permits. Biodegraded oil has been found in numerous mineral boreholes around the approximately 150km of strike length of the Carboniferous basin margin. Live oil was found in tight section in Ningbing -1. That the basin has generated and that a source is present is thus beyond doubt. It is probable that if the volume of sediment represented by the oil shows were statistically extrapolated then the volume of already "discovered" oil would be considerable. It thus remains to outline the relationships between source, seal, and reservoir; and structural and generative timing.

**Source:**

The known distribution of source material is confused by the stratigraphic uncertainties of the basin. TOC levels are lean to moderate in most of the shales ascribed to the Milligans Formation, but source quality is poor, i.e. gas prone. On the other hand, occasional samples yield "rock eval" results suggesting an oil prone source. The Milligans Formation in general is suspected to be the major sourcing sequence but, at this stage, no clear pattern has been established of the source distribution within this unit. With a maximum thickness exceeding 1500 metres, there appears to be a more than adequate volume of Milligans Formation to source economic hydrocarbon accumulations, even if the proportion "source" material within the formation is relatively low.

An algal origin has been suggested for the oil in Ningbing -1 on the basis of its composition. Certainly both the Famennian and Tournaisian carbonate sections are conceptual sources from algal material, but there is no quantitative data supporting this idea. Similarly, argillaceous interbeds and facies of both Tournaisian and Famennian age section have been only sparsely sampled. In the absence of significant data it is reasonable to impute some source potential to shallow marine silts, shales, and argillaceous limestones in this section.

The source potential of the Frasnian section is not known. This has never been drilled and only resistant sandy units and rare carbonates appear in outcrop. Most of the section is thought to be shallow marine and could therefore have at least modest source potential. The underlying Cambro-Ordovician basin could also have source potential, but any such potential cannot be reasonably assessed at this stage.

**Seal:**

The onlapping silty shales of the Visean Milligans Formation provide an excellent regional seal up to the margins of the Carboniferous basin. Intraformational seals are common in the Famennian section and probably adequate in the later Frasnian section. Seal is only a problem for sediments younger than the Milligans Formation.
Reservoir:

Section with reservoir potential is a minor component of the basin. Units with good reservoir potential are present, but their distribution is poorly understood. Reservoir is the most significant constraint on the prospectivity of the basin and to a large extent the search for oil becomes a search for reservoir.

Thin, and probably lenticular, sands of the Milligans Formation were gas productive in Bonaparte -2. Sands which produced gas in Keep River-1, Weaber -1, and Garimala -1, have usually been assigned to the Enga Sandstone of Tournaisian age. These sands could alternatively represent coarser developments towards the base of the Milligans Formation and be of early Visean to Tournaisian age. If this is the case, they would be better compared with the Zimmerman sandstone in outcrop. The outcrop type section of the Enga Sandstone is a much cleaner and thicker unit than that encountered in the wells. The position of the Enga Sandstone outcrop at the southern end of the Burt Range Syncline together with seismic evidence suggests that the Enga sandstone sensu stricto could be confined to the structural lows and this point will be further discussed under the "Play Concepts" heading. Conceptually, both Visean and Tournaisian sands could clean up into more effective reservoirs at their onlap edges at the basin margin where shoreface environments should have existed.

Porous and friable sands of probable late Frasnian age have been observed at the western edge of the northern Ningbing Range, (Gausden 1986, with an additional observation in 1989). These appear to constitute an important additional clastic reservoir objective. Similar sands were also observed in the Buffalo Hills area at the north east basin margin, but it is not known if these sands are Tournaisian or Frasnian. Sandstone in borehole NBL1001 in this area had 30.6% porosity and 3056 md. permeability at 126 metres. At this depth the sediments appeared to be still within the weathered zone and porosity may thus have been enhanced. Sandstone at 253 metres in BGD-5 was also excellent reservoir with 2828 md. permeability and 17.7% porosity, but again this sand is conceivably either Frasnian or Tournaisian.

The lowermost sand in Ningbing -1 had porosity up to 15.7% and permeability to 68 md. over some 25 metres. If this is a Frasnian sand (see Review and Discussion) then the reservoir potential of the late Frasnian section is confirmed. If it is of Tournaisian age, the results add weight to the suggestion that these sands clean up at the basin margin.

Potential reservoir sands are also present in the shallow Upper Carboniferous section, particularly in section usually assigned to the Tamurra Formation.

Carbonates are the wild card in the basin. Four of the eight petroleum exploratory wells have penetrated substantial carbonate section and found it tight. This is not the case with the mineral boreholes at the basin margin. Dolomitized carbonates of the Burt Range Formation commonly display vugular porosity, usually moldic, although some zones with intercrystalline porosity have
been observed. A substantial intersection of good sucrosic medium crystalline dolomite is also present in a number of boreholes to the east of Spirit Hill -1. The stratigraphic position of this carbonate unit is not clear, but it may be a dolomitized equivalent of the either the Septimus Limestone or the Burt Range Formation. Some limited sampling of the above units was recently undertaken and core analysis showed porosities up to 24.4% and permeability to 947 md.

Considering the age and burial and deformational history of the carbonates, the preservation of primary porosity is not to be expected even in any true reef facies that may be present, although reef could constitute a favoured host for secondary processes. Mineral exploration has established the presence of pervasive dolomitization, at least at the basin margin, and deformational processes appear to provide the major controls on dolomitization. The great bulk of the carbonates are platform "back-reef" facies and the probability of a "random" exploration well such as Keep River -1 or Weaber -1 encountering a porous dolomitized zone must always be remote. Targeting a well in the vicinity of a margin controlling fault could be far more rewarding in terms of secondary carbonate porosity, either dolomitization or fracture porosity. This zone also presents the conceptual opportunity for dual targets with onlap and offlap edges of sandstones as discussed above.

Another unit worthy of mention is the Westwood Member of the Cockatoo Group. This is recognized at only one outcrop location in the north west of EP 126. It is a highly fossiliferous limestone and is thought to represent a patch reef, occupying a stratigraphic position near the top of the Cockatoo Group. The reservoir potential of this environment is unknown.

A further speculative reservoir play recognizes the probability that some of the basin margin carbonate was exposed prior to the deposition of the early Visean argillites. The development of karstic porosity at this time is thus a possibility. No evidence of this situation has been detected by the drilling to date.

Maturation:

Data from the basinal exploration wells suggests that the base of the oil window may be attained at depths in the 1500 to 2000 metre range. This usually involves Visean or late Tournaisian sediments in the basinal area. At the basin margin, however, reflectance equivalents as low as 0.45% have been recorded in shallow mineral bores, probably from shales of early Visean or Tournaisian age. These observations are in general accord with the likely burial history of the basin. The regional geology suggests that the late Carboniferous and Permian sediments probably transgressed well beyond the present basin limits. These sediments have been removed by erosion, possibly at the time of Jurassic rifing which occurred to the north west in the now offshore area. The region was probably inundated again during the regional Cretaceous transgression and received a thin additional cover. These sediments were then eroded during Tertiary to recent time. Alternatively the whole additional sediment load may have been removed during Tertiary to recent time.
Geochemical sampling is still too sparse and the maturation indicators too coarse for a reliable reconstruction of burial history on this basis. The general picture is reasonably clear and suggests that an oil window exists from near surface to 1500 meters and passes into progressively older sediments across the Carboniferous basin margin. In detail the situation is probably more complex. There may have been localized thermal events particularly in association with the Mississippi Valley type mineralization of some carbonates. Proximity to older basement in areas such as the Pincombe inlier could also have produced locally higher heat flows. The most reliable measurements of present day geothermal gradient are from Weaber -2A, 42.2 °C/km, and from Garimala -1, 49.7 °C/km.

No estimates of the palaeogeothermal gradient have been made for areas where Frasnian section is at, or near outcrop. It can be noted that in the Canning Basin good oil shows have been obtained in Frasnian section as deep as 2300 metres. Some caution should be exercised before any portions of the Bonaparte Basin are condemned as being overmature for oil.

Structural Style:

The basin should be viewed in terms of three structural tracts. The Shelf Tract refers in particular to the western or Carlton Shelf area. Here, sediments of Cambrian, Ordovician, and Upper Devonian are in outcrop across a width of up to 60 kilometres in the northern portion of the shelf. The shelf has been little studied, particularly with regard to structure. Structuring, as seen on air photo and remote sensing imagery, is dominated by a north north west trending fault system with subordinate fairly high amplitude short wavelength folding. Some important cross trends are also present. The pattern is at least superficially suggestive of a compressional shear regime. It is most important to realize that this structural style persists eastward across the Ningbing Range, at least up to the point where sediments assume a strong eastward dip towards the Carboniferous basin. In more detail this means that the lower units of the Ningbing Group, specifically the Djilirri Limestone and the Kamilili Formation are definitely involved in this structuring, whereas the involvement of the upper unit, the Garimala Limestone, is arguable. It is also relevant to note the continued reluctance of workers to recognize this structural deformation of the Ningbing Group. Mory & Beere (1988, pp. 98, 99, figs. 91,92) treat a tight anticline west of Tanmurra Bore as if the western limb were defined in depositional dips, and consequently have some difficulty explaining the presence of both east and west dipping marginal slope facies.

The Basin Tract refers to the area of thick Carboniferous sedimentation occupying the major portion of the onshore Bonaparte Basin. Knowledge of the structural style of the basin tract is limited as, although considerable seismic effort has been expended, quality of the resulting data is generally poor. The area does clearly lack the tight folding of the shelf tract. One major recognizable feature appears to be a broad rollover towards the western margin possibly with an associated Carboniferous listric growth fault zone. Present indications are that the basin tract is quite weakly folded, but several generations of growth faulting, and subsequent faulting, may be present. These features
are more characteristic of an extensional regime, and if this is the case, a major change in structural style has occurred between the late Famennian and the Visean. There is also some evidence of salt involved tectonics in both the north west and north east of the basinal tract. This aspect requires further study.

The Margin Tract refers to the zone where the sediments of the basin tract onlap the sediments of the shelf tract. The margin tract is perhaps not strictly a separate entity, but in spatial terms represents the volume of sediments occupying the interface between the two major tracts. In the time framework this is centred on sediments of Tournaisian age.

Structural and Migrational Timing:

Given the number of unresolved problems regarding the stratigraphic succession in the basin, it is not possible to arrive at a definitive structural history at this stage. Rather than attempt to canvass all possible permutations permitted by the available evidence, a few aspects important to petroleum exploration can be highlighted. In the first place, as the fairly tight folding seen in the Frasnian and Famennian sediments is not evident in the Visean section, it is reasonable to assume that the compressional component of deformation largely died out during the Tournaisian. This statement must be qualified a little as some "wavy" irregularities in the onlap zone of the Visean section could be interpreted as a continuation of an element of wrench movement into the early Visean. It is also necessary to "collapse" the shelf tract in order to allow the formation of the Visean basin. Some workers envisage uplift and deep incision of the shelf during the Tournaisian, and consider that the subsequent Visean argillites bury this topography without there being necessarily any continuity of structural growth. It is possible to interpret seismic sections, particularly in some southern areas, to show a substantial late Tournaisian palaeotopography. Other interpretations can be made. On a regional scale it seems more reasonable to assume that Visean deposition and "collapse" of the shelf remained essentially in balance as the Visean basin expanded. If the roll into the basin margins developed by a growth fault mechanism during the Visean, then it would appear that all the major known structural elements, with the possible exception of salt intrusion, pre-date the late Carboniferous.

Exactly how early deformation of the shelf tract may have commenced is not clear. The recognition by Mory & Beere (1988) of unconformities within the Ningbing Group suggests that structural deformation may have been initiated in the Famennian, but not to the extent that deposition was interrupted for more than short periods of time. The preponderance of limestone breccias in the late Famennian Garimala Limestone may also be related to episodic fault movement.

On present evidence, sediments of earliest Visean and Tournaisian age, are those most likely to contain oil prone source. These sediments would have attained a depth of burial of around 2000 metres in the central basin area by the end of the Carboniferous, and considerably less at this time at the basin margins. Excluding any abnormal heating events, peak oil generation in the central basin is not likely to have occurred any earlier than the early
Permian in the central basin, and would have commenced progressively later toward the basin margins. Any source in the younger Carboniferous section is not likely to have generated until the basinal areas received their full sediment loading, possibly at the end of the Permian or even as late as the Cretaceous. The lack of any geochemical data on the Frasnian section and the poor knowledge even of the thickness and distribution of its stratigraphic units makes its generative history difficult to estimate. It is almost certainly well overmature for oil generation and preservation in the basinal areas, but its level of maturity in the shelf and margin tracts is unknown.

Summary:

1. Adequate source is present.
2. Seal is plentiful.
3. Reservoir is present, but sparse.
4. The basin has generated both oil and gas.
5. Structures are timely.
6. The oil window is shallow.

These points and other aspects of the hydrocarbon potential are further dealt with under the heading of "Play Concepts".
The key geological task yet to be completed on the way to an oil discovery in this basin is to arrive at a basin model that is consistent with the outcrop data, the mineral borehole data, the exploration well data, and most importantly, the seismic data.

Seismic quality varies from fair to abysmal. The most recent seismic shot in the Waggon, Redbank, Pincombe, and Bundaberg areas of the margin tract is of fair quality and outlines some of the most prospective leads covered by this report. Data quality deteriorates into the basin tract. No single reason for the poor quality has been established by previous operators. It may result from a combination of factors, such as the presence of high velocities in the shallow section and perhaps common small scale faulting. Conglomerates in the shallow section could also be implicated, as could the possible involvement of salt in the tectonics of the basin tract.

The widest variety of plays, including the more complex, occur in and adjacent to the margin tract. The most obvious feature of both western and eastern margins is the strong event dipping into the basin at 10° to 30° On the Carlton margin this event is usually referred to as the top of the Ningbing carbonate complex, but it is better defined as the base of the sequence which transgresses it, and is picked at the terminations of the onlapping events. The equivalent event on the eastern margin is also most likely underlain by carbonates and outcrop and borehole data would place these carbonates at no older than Burt Range Formation. A key question is whether or not any younger carbonates of the Langfield Group underlie this event in any areas. Structural features (see later discussion) on the Pincombe margin and at Weaber are also outlined and flanked by this event and buried by the onlapping sequence.

It is clear that this sequence boundary represents a fundamental change in depositional and structural style. For the sake of brevity it will be referred to as the "Tournaisian Unconformity" or "TU" in this report. It should be noted that the time interval represented by this unconformity may vary across the basin. The age of sediments in juxtaposition across the unconformity is, of course, also variable.

The silty shales of the onlapping sequence can largely be referred to the Milligans Formation. What has not been clear, however, is the age and nature of the lower portions of this sequence. This section shows reasonable seismic character suggestive of more variable and interbedded lithologies than those of the Milligans' shales. The "Lower Milligans" sequence wedges out well before outcrop on the margins, precluding direct correlation with the outcrop geology. The uppermost portion of this sequence wedges out onto the ramping "TU" event, but the relationship between the remainder of the sequence and the sediments below the "TU" is of particular interest. The situation at the "foot" of the "TU"; that is, the down dip termination of the basinward dipping margin tract, is open to a number of interpretations. In planning the Garimala -1 well in EP 126, the operator carried an event basinward from the foot of the "TU" and assumed it represented
near top Cockatoo Group, on the basis of the reported results of Ningbing -1. This assumption implied that the "TU" was an erosional unconformity and that this unconformity also carried out into the basin. This interpretation proved to be incorrect. Seismic correlations carried out for this study, suggest that Garimala -1 penetrated a major portion of the "Lower Milligans" sequence in a location basinward of the margin tract. This section included substantial sandstone intervals, carbonate cemented in part, and part of marginal reservoir quality. Palynology indicated an early Visean to Tournaisian age for most of these beds in Garimala -1 with the lowermost portion of the section penetrated being of possible late Famennian age.

This result still leaves the situation at the margin edge unclear. On many sections it is possible to interpret a growth fault at the downdip termination of the "TU" event. This is the point where the basal onlap sequence boundary passes basinwards into an apparently conformable sequence. If a growth fault is present then sediments beneath the "TU" may abut considerably younger sediments across the growth fault. This interpretation would accommodate both the conodont dating in Ningbing -1 and the results of Garimala -1. On the other hand, other sections, such as 88-426, strongly suggest a purely facies boundary at the margin edge. In this case the "TU" carries basinward as an entirely conformable event, and sediments beneath the "TU" at the margin edge are, of necessity, time equivalents of the sediments of the "Lower Milligans" sequence. This interpretation accommodates the alternative (palynological) dating in Ningbing -1, and is also consistent with the results of Garimala -1.

It is not inconceivable that both situations suggested above may coexist along different portions of the margin. In this case, whether the margin edge is a growth fault or a facies boundary will depend on the structural history of the fault block making up that particular segment of the margin. It should also be noted that in the Waggon area, at least, the "TU" is incontestably an erosional unconformity (line 87-303), but only where the "TU" is dipping to the south into the "Waggon Graben". This observation, together with the possibility of a buried palaeotopography in the southern part of EP31, leads to the suggestion that, apart from all other structural movements, a south to north tilt may have applied briefly at "TU" time, giving rise to a greater possibility of subaerial erosion occurring on southern structures.

On the basis of both its Garimala dating and its spatial position, it is reasonable to assign most of the "Lower Milligans" sequence to the Langfield Group. It is relevant to note that the units of the Langfield Group are defined from the Burt Range Amphitheatre area, and that this area is essentially an exhumed synclinal core. The type area for the Langfield Group thus appears to describe the "off structure" facies of the Group and not necessarily the units which would be found on structure or beneath the "TU" in the margin tract.

Further seismic character correlations into poor quality data along the central and northern portions of the western margin tract suggest that the "Lower Milligans" sequence is uniformly distributed along the entire western margin, but does not generally reach outcrop. As a consequence of this observation and
the assignment above, it is possible to assert that equivalents of the entire Langfield Group (formerly the Keep River Group) are present at, and wedge out onto, the western basin margin. As will be discussed later, correlatives of specific units of the Langfield Group may also be present.

It should be mentioned that the terms Bonaparte Formation and "Bonaparte Beds" have historically been used to describe a large portion of the basinal section. It would be most reasonable to restrict the usage of Bonaparte Formation to cover undifferentiated shaly equivalents of the Langfield Group. "Kamilili Formation" (Mory and Beere, 1988) may be used for any undifferentiated shales of Famennian age.

From a broader viewpoint, the forgoing discussion is leading to a "Model 2" type interpretation. It appears that the distribution and facies variations of the Tournaisian and late Famennian sediments are intimately tied up with the structuring of the basin, but of the early Famennian and the Frasnian we know little. A deep, truncating, unconformity is seen on some sections, eg. 88-412 and 88-402. This has been designated "FU" and could represent either a Famennian or Frasnian unconformity, or possibly even a base Devonian unconformity. It is thus not known if the sediments being truncated are of Frasnian, Cambro-Ordovician or Proterozoic age. On the basis of outcrop evidence there should also be at least one important unconformity within the Famennian section in the margin tract. It would be overly optimistic to claim that such an event could be picked on the existing seismic.

Summary of Basin History:

3. Late Ordovician to early Devonian: Hiatus, erosion?
4. Late Devonian, early Frasnian: Major movements on neighbouring cratonic blocks. Deposition of synorogenic conglomerates along the Halls Creek Mobile Zone, and widespread deposition of sandstones across the incipient basin.
5. Frasnian: Deposition of a number of cycles of largely shallow marine sediments. The sequence as a whole tending to fine upwards as structural movements declined in the sediment source areas. Carbonate deposition and patch reef formation included in the final deposits of this phase.
6. Early Famennian: Widespread deposition of limestones and marls over a broad shelf. The palaeogeography of this time is uncertain.
7. Mid Famennian: Initiation of the structural movements which determined the geometry of the later Carboniferous basin. Probable development of growth faults possibly with associated reefal margins. Continuing carbonate deposition probably giving way to argillaceous micrites and shales in the direction of the developing basin. Some erosion possible away from the basin.
8. Late Famennian to early Tournaisian: Continuation of above, probably with a number of cycles of advancing and retreating carbonate deposition including periods of platform destruction with the resulting deposition of extensive carbonate breccias.
9. Mid to late Tournaisian: Clastic influx, including fine and medium sandstones and siltstones, leading to only restricted carbonate deposition and to common mixed carbonate clastic lithologies. Clastic influx probably related to a regional uplift
and a corresponding reduction in the area of the Tournaisian basin, and to erosion of the basin margins.

10. Late Tournaisian to earliest Visean: Incipient "collapse" of margin. Final phase of carbonate deposition (Septimus Limestone and equivalents) around the margin of the reduced basin.

11. Early Visean: Commence deposition of a clastic sequence to continue at an increasing rate as subsidence gathers momentum. There appears to be components both of local subsidence leading to tilting of the basin margin and of regional subsidence drowning the whole area including the previously eroding margins. The basinward tilting of the margins could be attributed to a change from a compressive structural regime, in the Famennian to Tournaisian, to an extensional regime in the Visean. Alternatively, a compressive wrench system could be considered to have persisted into the Visean, but with the regional subsidence overwhelming the relative uplift of the basin margins. The earliest Visean sediments probably include significant sandstone intervals at least towards the margin, but the bulk of the Milligans Formation consists of silty shales with only occasional sandy intervals. The base of this sequence represents the upper time limit of the "TU" unconformity.

12. Late Carboniferous: Shallowing of the basin allowing the deposition again of higher energy sandstones, with occasional carbonates in protected environments (Tanmurra Formation). Then further shallowing with the progradation of fluvial and deltaic sandstones over the basin in generally upward coarsening cycles (Point Spring Sandstone, Border Creek Member).

13. Late Carboniferous and early Permian: Fluvial and fluvioglacial sediments probably followed, with mild unconformity after minor deformation in the late Carboniferous.

14. Permian: It is probable that at least a portion of the extensive marine Permian section that is present in the offshore also extended over the onshore basin, but has since been eroded.

15. Triassic, Jurassic: Hiatus or erosion. Possible minor reactivation of faults or imposition of a new secondary field, during offshore Jurassic rifting.

16. Cretaceous, early Tertiary: Possible thin additional sediment cover added during and after the Cretaceous transgression, and later eroded.

17. Tertiary to Recent: Erosion.
PLAY CONCEPTS

This discussion is primarily directed at the oil potential of the basin. The gas potential of course cannot be ignored and some commentary on gas plays is included. Five general play settings together with their "sub-species" are outlined below.

Type A: Plays in the Margin Tract:

The margin tract is likely to contain the most favourable geometric relationship of reservoir and source sediments in the basin. Furthermore, these sediments are expected to be within the oil window from about 500 metres to 2000 metres depth. The same sediments are thought to be generally below the oil floor across the basinal area and are absent by non deposition or erosion on the shelf. The margin tract is poorly endowed with simple anticlinal fold closures. This is probably the main reason that only one well, Ningbing -1, has addressed the western margin tract. However, structural closures are present, and the margin has considerable potential for stratigraphic and structural stratigraphic combination traps. The ratio of seal to reservoir is also high, enhancing the probability of closure for any potential stratigraphic or fault traps.

Type AA Structural Closures:

AA1: Substantial high relief closures have been delineated on the east margin of the Pincombe Inlier. These can be classified loosely as "carbonate build-ups", but a number of mechanisms for their origin may be postulated, including; buried topography, growth fault blocks with or without carbonate build-up and with or without topographic elevation and erosion, and even salt influenced structures. The Weaber gas discovery appears to overlie a carbonate platform of similar origin. Similar features may conjecturally be present in the Bundaberg area, both high on the margin and more deeply buried to the north east of Weaber. The Pincombe west margin and the more basinal area to the north east along the Pincombe high trend are also areas where further examples of this feature may eventually be located.

AA2: Structural leads involving the "Lower Milligans" sequence are identified in a number of areas in, or near to, the margin tract. These are often subtle and usually have the form of rollovers into the margin faults. Where there is a possibility that part of the "Lower Milligans" sequence lies within the oil window then these leads are designated as type AA2.

AA3: Refers to other, not readily classifiable, potential structural closures within the margin tract.

Type AB Stratigraphic Plays:

In some compensation for the lack of folding, the setting of the margin tract with respect to stratigraphic closures is excellent. Up to 2000 metres of section wedges out across both the eastern and western margin tracts with the upper portion of this section being the overstepping sealing shales of the Milligans Formation.
The "Lower Milligans" sequence (Langfield Group equivalents), discussed under "Seismic Stratigraphy" above, may contain important reservoir units. The sequence appears to be involved in a regional wedge-out around the whole basin margin. Some areas recognized to date where it may be involved in either embayment traps, (Type AB1) or pinch out onto structural noses (Type AB2), and lie within the oil window, are; the Pincombe east margin and the Burt Range Syncline, and the Redbank to Waggon areas. The above areas lie in the south of the basin. Deteriorating seismic quality makes it difficult to reliably trace the sequence along the margins to the north. The impression gained at the western margin is that "Lower Milligans" zero edges become progressively more deeply buried northward of the Waggon area. However, the sequence appears to be brought into a shallower position in the Brolga area where the margin becomes segmented into several fault blocks. Interesting structural, or combination structural and stratigraphic traps, are possible in this area.

Plays in the onlap sequence may not be confined to the "Lower Milligans" sequence. Sandy "edge" or shore-face facies of the Milligans Formation may be present. For example, an equivalent of the gas productive sand in Bonaparte-2 could clean up into an attractive oil target at shallow depth at the margin.

Type AC Stratigraphic Plays:
This play type refers to possible stratigraphic wedges beneath the "TU". Seismic sections on both the east and west margins appear to allow for considerable scope for this type of play although the nature of the underlying section cannot be reliably predicted. The Ningbing -1 problem is relevant to this play. If the sand at TD in Ningbing -1 is Tournaisian and not Frasnian as currently thought, then a major Tournaisian wedge exists beneath the "TU" in the Ningbing area. If it is Frasnian after all, then a truncation trap or a fault block play could be present in the vicinity. Type AC plays may be postulated in all of the margin tract areas. A variety of truncation, pinch out, and fault block plays could be envisaged, singly, or in combination. At this stage, the lack of good seismic definition beneath the "TU" precludes any useful subdivision of this play type. The sparse drilling control together with the ambiguous biostratigraphic evidence also precludes reliable prediction of the distribution of potential reservoir units beneath the "TU". It is suspected that at least some units of the Langfield Group, as defined in outcrop, occur beneath the "TU" in at least some parts of the basin. Just which Tournaisian aged units occur above, and which below the "TU", and over what areas they are distributed, are questions central to the prospectivity of the margin tract. These questions can only be addressed by further drilling in the margin tract.

Type AD Truncation Plays at the "TU":
In some portions of some southern areas, events beneath the "TU" are truncated by the "TU" giving the appearance of a major erosional unconformity. In the Waggon area existing seismic suggests a substantial sub unconformity trap in conjunction with a type AB play in the overlying sequence. There appears to be
potential for similar situations in the Burt Range Syncline area. This play type would also include any back dipping fault blocks which may be present on either the eastern or western margins. As previously discussed, it is not yet possible to predict the stratigraphy beneath the "TU" and sediments of any age from Frasnian to Tournaisian may be present.

Type B: Structural Closures in the Shelf Tract and at the Shelf/Margin Boundary.

Type B1: These structures can be broadly described as faulted anticlines, probably passing into fault blocks at depth. Late Frasnian and early Famennian sediments should be involved in these traps at relatively shallow depths. There is no direct evidence of the level of maturity of these sediments in this situation but by inference from data from the margin tract there is a reasonable possibility that they lie within the oil window. The source potential of the enclosing and underlying section is unknown. Lateral sourcing from the margin tract is also possible. On the basis of outcrop evidence, possible reservoirs are late Frasnian sands, late Frasnian patch reefs, and early Famennian dolomites.

Type B2: The deeper section of the major fault block trends could have substantial potential as a gas play from early Frasnian sands of the Cockatoo Group.

Type C: Structural Plays in, or adjacent to, the Basin Tract: Type CA: Shallow Oil Plays:

The recent discovery of oil in Upper Carboniferous sediments at Barnett -2 in the near offshore Bonaparte Basin has confirmed the potential of this portion of the section. In the onshore basin, the recent Garimala -1 well had good oil shows from about 700 to 1000 metres in the upper portion of the Milligans Formation (Visean). Weaber -1 and Spirit Hill -1 also recorded oil traces from this section. These results tend to confirm the source potential of the sediments underlying the Upper Carboniferous section in the onshore basin.

A paucity of reservoir quality sands is the main constraint on the type CA play where Milligans Formation sediments are involved. One oil show zone in Garimala -1 tested tight. Other shows were left untested behind surface casing but it is unlikely that any potentially productive zones were overlooked. If some areas of the Milligans Formation can be shown to be more sand prone, then this play may be worth pursuing. A further situation that must be included in this play type is the possibility of an oil leg to gas sands within the Milligans Formation. Bonaparte -2, for example, tested at 1.54 MMCFD from a Milligans Formation sand at 1439 metres. An evaluation of the well by Santos Ltd. in 1988 includes the assertion that there is no downdip liquids potential, on the basis of low C5 computed from a normalized analysis of an air contaminated gas sample. It is doubtful that this conclusion can be fairly drawn from the data available. The gas at Bonaparte -2 should certainly not be classified as dry. However, even if an oil leg does exist in situations analogous to Bonaparte -2, it will be necessary to identify more favourable sand trends within the
Milligans Formation before this play is likely to be commercially productive.

It is also important to consider the potential of the post Milligans Formation sediments in the onshore basin. Upper Carboniferous section in the subsurface is usually referred to the Tannmurra Formation and is seen to contain good reservoir quality sands. These were tested in Bonaparte -1 and produced fresh water. If structural closure existed at the Tannmurra level then this result illustrates the main constraint on the prospectivity of these sands. The Tannmurra Formation and the partly equivalent Point Spring Sandstone reach outcrop around the perimeter of the basinal tract, except in those areas where it may be overstepped by the depositional edge of the early Permian Border Creek Formation. The earliest Permian sediments appear to be dominated by sandstones and conglomerates, thus the Tannmurra Formation, by and large, lacks seal.

Given the lack of drilling control in northern areas, the above generalization should not be taken as condemnation of the play. Areas more distant from outcrop and with a thicker Lower Permian cover could be prospective. Interbedded sandstones in the Tannmurra Formation to Milligans Formation transition zone would also be of considerable interest. Seismic quality in these areas is mostly very poor, but reprocessing directed at the shallow events could be beneficial. The extent and style of structuring in these northerly areas is largely unknown, but it may well be the case that the most prospective areas for this play occur in conjunction with the possible salt related features discussed below.

Type CB: Gas Plays:

Type CB1, Carboniferous:

The bulk of exploration to date has been directed towards delineating simple anticlinal closures in the basin tract, i.e. type C structures. This is conventional geophysically based exploration. The result has been four potentially economic or sub-economic gas discoveries from sands within the Tournaisian to Visean section. These were Keep River -1, Bonaparte -2, Weaber -1, and Garimala -1. There is ample evidence in each of these widely spaced wells of a potentially large gross hydrocarbon column. The constraint in all cases is the lack of good reservoir quality sands. There is thus a large conceptual gas resource contained in the onshore Bonaparte Basin. This resource will only become economically exploitable if the geological controls on reservoir distribution can be determined.

There is untested potential for type CB gas plays in the northern areas of both EP126 and EP31. The possibility of coincident or downdip type CA oil plays should provide sufficient incentive for further exploration of these play types.

Type CB2, Frasnian deep gas plays:

There has been no valid test of Frasnian section within the onshore Bonaparte Basin. A number of wells are commonly depicted as having reached Frasnian section. Keep River -1 may have just
reached a tight Frasnian sand at TD. but structural closure for this well is dubious. Bonaparte -1 almost certainly did not penetrate Frasnian section and again, structural closure is dubious. The Ningbing -1 situation has been discussed in some detail above. The basal sand in this well may be of Frasnian age but there was certainly no structural closure at this depth. Similarly, Spirit Hill -1 may have reached Frasnian section but no structural closure is present.

In a broad sense the Frasnian section fines upward. There is ample outcrop evidence of massive cross bedded medium and coarse grained sandstones in the lower portions of the Cockatoo Group. There is no evidence that these sands pass out into a basinal facies corresponding to the later Carboniferous basin. There is also some outcrop evidence of porous sands in the uppermost portion of the Cockatoo Group.

Recent seismic surveys give some indication of a deep unconformity involved in the roll into the basin margins. This unconformity may represent the top of the Cockatoo Group ("FU"). In order to test this section along the Garimala-Bonaparte Trend or the Legune Trend it may be necessary to drill beyond 5000 metres. Preservation of porosity at this depth would be the major risk factor. It would also be difficult to isolate closures along these general trends unless an improvement in seismic quality can be achieved. If the deep gas play is valid, potential reserves would be very large.

**Type D: Salt Related Plays:**

Salt diapirism in the offshore basin is well documented. Pelican Island -1, in the near offshore adjacent to EP126, intersected a salt body at about 1800 metres. A number of features on seismic lines in the northern onshore basin are suggestive of salt influence, particularly in the Brolga and Legune areas. It could even be suggested that the type AA structures in more southern areas are salt related, but there is no independent line of evidence leading to this conclusion. Several Landsat and airphoto anomalies suggestive of salt intrusion have also been detected and some relationship between these features and gravity lows can be noted. Further work is in progress on this aspect.

At this stage, the actual salt related play types must remain fairly speculative, particularly as the timing of emplacement is unknown. It would also be helpful to know the age of the source salt deposit as it is not clear whether the salt is originating from early Devonian, Silurian, Cambro-Ordovician, or even earlier section. If the emplacement was early, sedimentation above the feature may have been influenced, producing local facies variations. Late emplacement may produce a range of structural and structure/stratigraphic traps. Offshore seismic shows some diapirc bodies intruding to the sea floor, but it cannot be concluded that this late emplacement was either general or the only phase of salt movement.
SUMMARY OF HYDROCARBON POTENTIAL

OIL

1. Primary targets for oil plays are considered to lie within, or adjacent to, the margin tract, at depths between 500 and 2000 metres.

2. A secondary play may exist at similar depths in the basin tract, but the reservoir distribution and the reservoir to seal relationship is considered to be less favourable. Salt related features could be of particular interest with respect to this play.

3. With the possible exception of type "B" structural plays, all plays, including those with structural closure, will have some element of stratigraphic control.

4. Primary reservoir objectives are perceived to be, in order of preference:
   (a) Tournaisian shore face and marine sands. (conditional on the resolution of the stratigraphy of such units)
   (b) Early Visean transgressive shore face sands.
   (c) Late Frasnian marine sands.
   (d) Tournaisian dolomites.
   (e) Famennian dolomites.

5. Secondary objectives may include:
   (a) Other Visean sands.
   (b) Later Carboniferous sands, where sealed.
   (c) Frasnian carbonates, if present.

6. The intensity of structuring, and the stratigraphic variability of reservoir, suggest that a mean target size of less than 10 MMSTB recoverable can be anticipated.

GAS

1. Gas bearing sands have been intersected in five of the eight exploration wells drilled to date, in either the Milligans Formation or Langfield Group equivalents.

2. Intersections in Ningbing -1 were not associated with any structural closure. Bonaparte -2 may also have been outside closure, and the situation at Keep River -1 is similarly uncertain.

3. The regional wedge out of predominantly sealing Carboniferous sediment onto both western and eastern basin margins could enclose a substantial gas resource, largely independent of structure.
4. Intersections to date indicate a low deliverability for wells drilled into this section. A search for better reservoir quality at the basin margins could be rewarding.

5. There is substantial untested structural potential involving the Carboniferous section, updip and to the north of Bonaparte -1 and Bonaparte -2. At this stage there is no data to suggest that reservoir quality will improve in these updip areas.

6. There is a conceptual possibility of a very large gas resource reservoired in Frasnian sands, at depths probably exceeding 4000 to 5000 metres in the basin tract. The major problem is to map closure at this depth, and the major risk will be preservation of reservoir quality.

7. The prime areas for the deep Frasnian play appear to be along the length of the roll into the western margin (the Garimala - Bonaparte Trend), and possibly along the Legune Trend in EP 31.

8. It may be possible to address the Frasnian play at moderate depths in the margin and shelf tracts, but in these areas the size of potential closures may be limited by a lack of seal against adjacent fault blocks.
EXPLORATION RECOMMENDATIONS

Exploration programs in the onshore Bonaparte have tended to falter because of a "catch 22" situation. The indifferent quality of all but the more recent seismic, taken together with the complex structural style and stratigraphy, has prevented the delineation of conventional geophysically based drilling targets. This has lead to a lack of drilling control, but more drilling control is precisely what is required to mature the more complex plays that the basin does present. The results of the 1987 and 1988 seismic surveys give some indication that acquisition and processing technology has reached the point where usable data can be obtained, at least at the cost of a high effort survey. Even so, it will be necessary to resolve the existing stratigraphic problems in some detail before the existing and future seismic data can be interpreted with confidence.

It is clear that, in order to advance exploration and hence achieve an economic discovery, it will be necessary to initially drill at a higher level of risk than the current norm.

Slim hole drilling may offer an avenue whereby drilling costs may be reduced in proportion to the perceived exploration risk. Fully cored slim hole drilling also provides maximum stratigraphic information from the well. This is attractive, as stratigraphic control is an important component of many of the plays. These remarks apply in particular to the nominated oil plays, as the oil floor is suggested to be appropriately shallow at 1500 to 2000 metres.

A number of prospects suitable for a slim hole test are identified in this report. All could also be evaluated by a conventional well, but most would be considered to require additional seismic detailing in a conventional exploration program. On the other hand, all prospects are considered to have a reasonable probability of being valid tests of the plays described.

An additional factor to be considered is the extended wet season in this area, which makes it extremely difficult to both shoot seismic and drill on its results within the same calendar year.

The recommended strategy for oil exploration is thus to initially approach both EP31 and EP126 with a slim hole drilling program during the 1990 dry season. This opens the door to the chance of an early discovery, and will at least provide the drilling control necessary for a reliable interpretation of the seismic data. A different approach may be necessary if a serious attempt to prove up gas reserves is to be made.

The next questions to be addressed are when to initiate new seismic work and how much is required. The wet season mentioned above and the remoteness of the area indicate that economies of scale are appropriate. On the other hand, acquisition will be relatively expensive. There is absolutely no point making cost savings in the acquisition phase if the resulting data is
unable. There will also need to be some confidence that an improvement on existing data quality can be achieved.

In order to detail the prospects and leads outlined in this report, and to further address the more regional plays, up to 300 line kilometres could be laid out in each of EP31 and EP126 (including the adjacent area recommended for application). This would be a maximum initial program for the new exploration phase. In terms of allowing for continuity of exploration, it would be desirable to carry out this work during the 1990 dry season. The results would then be available for interpretation in conjunction with the results of the initial slim hole drilling. If the seismic is delayed to 1991 the results could probably not be acted on until 1992. On the other hand, exploration economics could preclude commitment to an extensive seismic survey in the absence of encouragement from the slim hole drilling results.

It should be pointed out that, for both permits, the Government work commitments allow for a flexible interchange of seismic and drilling in the second and third permit years. There is also no commitment to either seismic or drilling during 1990. For EP126 the second permit year ends in August 1991 thus seismic or drilling will need to commence early in the 1991 dry season at the latest. The situation is more flexible with respect to EP31, as the second permit year ends in December 1991.

At the time of compilation of this report it was expected that vacant areas adjacent to EP126 would become available for application early in 1990. This has not proved to be the case, due to delays in the gazetting of these areas and it is now unlikely that an application could be submitted and approved in time to allow for seismic acquisition during the 1990 field season. This factor, taken together with the current adverse economic climate, is likely to lead to a 1991 start to further seismic acquisition. A minimum initial program of 150 km. is recommended for both the NT. and WA. permit areas. An initial slim hole drilling program of two wells in each permit is similarly recommended, preferably to commence in 1990.

The question of whether or not a separate gas exploration program is warranted could also come under consideration during the year.

As soon as the vacant areas adjoining EP126 to the west and south are gazetted, immediate application is recommended in order to secure the Waggon stratigraphic play and structural plays on the western shelf.

Re-application should also be considered for the 12 blocks which constituted the last compulsory relinquishment from EP126. In a more optimistic economic climate, such re-application could be strongly endorsed in the light of increased exploration interest generated by the Barnett offshore oil discovery. At this stage, however, it is necessary to emphasize the likely excessive cost of seismic acquisition in the tidal flats and basinal areas when weighed against the apparently low probability of a "type CA" oil discovery, in so far as this can be assessed for this unexplored region.
Other Work:

1. Gravity.
As a result of the interest in the exploitation of possible diapiric salt bodies in the area, it is recommended that detailed gravity surveys be conducted over all seismic and Landsat anomalies. The detection of any salt intrusions may also lead to the delineation of related petroleum plays. The design of this program should follow a brief review of the existing gravity grid.

2. Reprocessing.
Rumph (1989) recommends further test reprocessing of the 1982 seismic data particularly in the Bonaparte/Opir area (Tanmurra and Brolga areas of this report), and in the Bundaberg area. He also notes poorer quality in the 1988 data compared to the 1987 data in the Siggins (Waggon) area, and suggests that less attention may have been given to velocity picking and muting in the later survey. The recommendation for reprocessing is endorsed as any improvement in quality in the northern areas obtained in this way will be very cost effective.

A review of the petrophysical logs of Ningbing -1 and Garimala -1 is recommended, in order to quantify the distribution of hydrocarbon in the section. It would also be valuable to commence some log based lithofacies work on these and the older western margin wells, as an understanding of the sand distribution is crucial to the optimization of the exploration effort. A better lithostratigraphic subdivision of the Milligans Formation and Langfield Group equivalents should also be achievable.

In order to avoid potential breaches of sacred site legislation, it will be necessary to precede any seismic or drilling activities with an anthropological survey, in consultation with the relevant authorities.

5. Structural Studies.
A better understanding of the structural style of the basin may be gained by combining the results of the existing thematic mapper enhancements with the field mapping observations. Coverage of the remainder of EP 31 that was not included in the original thematic mapper acquisition has been ordered.
PROSPECTS, LEADS, AND PLAY AREAS

The meaning of the terms "prospect", "strong lead", and "weak lead" have been widened from their normal usage in order to accommodate the stratigraphic component of many of the plays, and the possibility that a slim hole drilling program may be conducted at a higher level of risk than that generally accepted for conventional drilling. Thus "prospect" refers to any area where there is sufficient geophysical and/or geological data to suggest that a valid structural or stratigraphic closure could be tested by immediate drilling. Each prospect will require further review in order to estimate the expected value of immediate drilling by either slim hole or conventional techniques compared with the cost/benefit of additional geophysical work. The high cost of acquisition of usable seismic data is an important factor in this equation. "Strong leads" and "weak leads" refer to areas where additional geophysical and/or geological work is clearly required. The subdivision is a purely subjective ranking of the "distance" the lead is from prospect status. The term "play area" is used to refer to those areas where there is insufficient data to delineate specific prospects or leads, but where more regional considerations suggest that one or more of the play types outlined in this report may be present.
**EP-31**

**Prospects**

**PROSPECT NP1**

Play Type: AA.

Location: Intersection lines 88-510 and 88-503.

Description: High relief 4 way dip closure on "TU". Approximately 220 ms. roll on 88-503 and 150ms roll on 88-510. Critical closure to the south west not fully determined by seismic, potential for 100ms closure. Deeper section would rely on fault closure to the west.

Estimated Closure:
Area: 500 acres.
Vertical: Up to 200 metres.

Objectives: Tournaisian dolomites and sandstones at 350 to 850 metres, oil. Optional: Famennian to Frasnian carbonates and sandstones, from 1200? to 1800 metres, oil or gas.

Status and Work Recommendations:
Immediately drillable, or optionally one seismic line to detail closure. Seismic quality may preclude detailing of deeper potential dip closure. Ideal location for shallow slim hole test of the type AA play, with an optional extension to 1800 metres to identify and evaluate the reservoir potential of the deeper section at a location with a reasonable chance of being within fault closure at depth. Could also be considered for drilling with a conventional rig.

Possible Drill Locations:
Line 88-510, VP 460

**PROSPECT NP2**

Play Type: AA.

Location: Intersection lines 88-506 and 87-402.

Description: High relief feature as for NP1, but with modest dip closure on "TU" in critical west direction. Feature appears to be faulted against basement on the Pincombe Trend and there is potential for more substantial fault closure.

Estimated Closure:
Area: 400 acres.
Vertical: 45 metres 4 way dip, 150 metres fault dependent.
Objectives: Tournaisian sandstones and dolomites at 290 to about 600 metres, oil. Deeper section within possible fault closure, Frasnian? to Famennian? sediments from 600? to 1100 metres, oil.

Status and Work Recommendation:
Immediately drillable shallow slim hole location to test type AA play. Additional seismic would add little to risk assessment of this feature.

Possible Drill Locations:
Line 88-506, VP 812.

PROSPECT NP3

Play Type: AA.
Location: Intersection lines 87-403 and 87-404.
Description: High relief feature as for NP1, but "higher" on the Pincombe trend with less section between "TU" and probable basement. On the other hand, NP3 lies down plunge on the Pincombe Trend and is thus more deeply buried, i.e. by a thicker Milligans Formation cover, than is NP1. Critical closure to the south west is not covered by seismic, but the feature is probably closed.

Estimated Closure:
Area: 1000 acres.
Vertical: 200 metres?

Objectives: Tournaisian sandstones and dolomites at 900 to about 1200 metres, oil.

Status and Work Recommendation:
Could be considered as immediately drillable shallow slim hole location to test the type AA play, or as a conventional well location after additional seismic, particularly if results from the drilling of NP1 are encouraging. Additional seismic may be difficult to acquire due to access and sacred site problems to the south west.

Possible Drill Locations:
Line 87 403, VP 246

PROSPECT NP5A

Play Type: AB1.
Description: An extensive area where pinch out of the lower part of the post "TU" sequence is captured by the structural high features to the south, forming an embayment play.

Estimated closure:
Area: Up to 1500 acres.
Vertical Up to 150 metres.

Objectives:
Post "TU" sandstone and dolomites? from 700 to 1000 metres, oil.

Status and Work Recommendation:
Reasonably well defined by existing seismic and could be drilled immediately, particularly in conjunction with a well on an adjacent structural high. This would allow evaluation of the reservoir potential of part of the section absent on the structural highs, in a location with a good probability of stratigraphic closure.

Possible Drill Locations:
88-503, VP 463, or VP 510.
88-506, VP 1060.

PROSPECT NP5D

Play Type: AB1, AC?.

Location: Line SH84-10, VP400-900.

Description: Extensive pinch out onto the east flank of the Burt Range Syncline. Major portion of the broad NP5 play. Capture of zero edges to the south is not adequately covered by existing seismic. Outcrop evidence of a structural low lying to the south east suggests a reasonable possibility of closure. Section below the "TU" may also be closed to the east against a basin margin fault, forming a variety of the AC play type.

Estimated Closure:
AB1:
Area: 750 acres.
Vertical: 150 metres?

Objectives:
1: As for NP5A, from 450 to 750 metres, oil.
2: Carbonates and clastics below "TU" from 650 to 1000 metres, oil.
3: Unknown section to 2000 metres, oil or gas.

Status and Work Recommendation:
Could be considered for immediate drilling to evaluate section both above and below the "TU" at a fairly high level of risk of stratigraphic or structure/stratigraphic closure. The probability of obtaining seismic of quality adequate to better define the play must be weighed against the desirability of seismic detailing.

Possible Drill Locations:
Line SH84-10, VP 760 (to 1000 or to 2000 metres).
Line SH84-10, VP 600 (to 1000 metres).
STRONG LEADS

STRONG LEAD NP5B

Play Type: AB1.

Location: Line BR22, SP 1070-1080.

Description: A small embayment between structures NP1 and NP4.

Estimated Closure:
Area: 500 acres.
Vertical: 100 metres.

Objectives: As for NP5A, between 700 and 1000 metres, oil.

Status and Work Recommendations:
Could be considered for drilling, particularly as a follow up location to NP5A, but additional seismic definition would be desirable.

Possible Drill Locations:
Line BR22, SP1074.

STRONG LEAD NP5C

Play Type: AB1.

Location: Line 88-512, VP 550 to 600.

Description: Possible subtle closure based on slight roll on lines 88-512 and 88-510. This closure could enhance any stratigraphic closure resulting from the conceptual NP5 play. Neither stratigraphic nor structural closure is adequately demonstrated by the existing seismic coverage.

Estimated Closure:
Structural:
Area: 500 acres.
Vertical: 10 to 20 metres.
Stratigraphic:
Unknown, portion of NP5 play.

Objectives:
As for NP5A from 500 to 900 metres, oil.

Status and Work Recommendations:
Could be considered for drilling at high level of risk, but additional seismic would be preferable.

Possible Drill Locations:
Line 88-512, VP 570.
STRONG LEAD NB2C

Play Type: D.

Location: Line 88-514, VP 116 to 1260

Description: An intrusive body, possibly salt. There is a possibility of closure against this intrusion as well as facies changes influenced by the feature. Depth to the crest of the body is not clear, but appears to lie within the 500 to 750 metres range, thus there is also a possibility of a shallow crestal play.

Objectives: Probable Tournaisian section from 600 to 1000 metres adjacent to the feature, oil. Also, if salt, salts, sulphur, crestal.

Estimated Closure: Unknown.

Status and Work Recommendation:
A particularly interesting feature. A preliminary detail ground gravity survey is recommended, to confirm the presence of a low density body and to outline it. Seismic acquisition should conditionally follow.

STRONG LEAD NL1

Play Type: AA, CA, CB?

Location: Line 88-516, VP 500 to 660.

Description: Single line rollover of about 300 ms. on the "TU". There is also at least 40ms. of roll about 150ms above the "TU". Potential dip closure dies in the shallow section, but there is some suggestion in the poor quality data that up dip fault closure could be present. About 150ms. of section below the "TU" is truncated by the "TU" both to the north west and the south east. The feature has some aspects in common with the Weaber structure and the "TU" is at a similar depth.

On the basis of the results at Weaber -1 and Keep River-1, sediments below the "TU" may consist of tight carbonates, but reservoir may be present in sandstones in the post-"TU" section which has reasonable seismic character over the NL1 feature. Again on the basis of the Keep River and Weaber results, this section may be considered to be primarily prospective for gas. Any reservoir present in the later Carboniferous section may be prospective for oil.

Estimated Closure:
Area: 2500 acres (one line lead only).
Vertical: Potential for greater than 200 metres.
Objectives:
Sandstones of the "Tanmurra Formation" and Milligans Beds, from 250 to 1200 metres, oil (or gas). Sandstones of the "Lower Milligans" sequence, from 1200 to 1700 metres, gas (or oil). Pre-"TL" section carbonates and sandstones? from 1700 to 3300 metres, gas. Probably no closure below 3300 metres.

Status and Work Recommendation:
A strong seismic lead warranting detailing. An attempt should be made to enhance shallow events during processing.
WEAK LEADS AND PLAY AREAS.

WEAK LEAD NP4

Play Type: AA.

Location: Line 88-508, VP 600 to 700.

Description: Possibly a nose of the NP1 feature, but could be a separate culmination. East-west roll of about 100 ms. on "TU".

Estimated Closure:
Area: 250 acres.
Vertical: Up to 100 metres if separate culmination.

Objectives: Tournaisian sandstones and dolomites at 700 to about 1000 metres, oil. Deeper section within possible fault closure, Frasnian? to Famennian? sediments from 1000 metres to about 1400 metres.

Status and Work Recommendation:
Requires a detail line to establish closure from NP1.

PLAY AREA NP5

Play Type: AB?.

Description:
NP5 is a conceptual stratigraphic pinchout play located around a structural saddle on the Burt Range Syncline trend. Four prospect suit areas have been broken out on the basis of existing seismic. Post "TU" sediments maintain a roughly uniform thickness across the synclinal axis, and the lower portion of this sequence pinches out against the "TU" on both flanks of the syncline. The overall impression is that of a "valley" fill sequence with some later deformation. The broad concept is that outcrop evidence suggests that the syncline plunges both to the north and to the south, away from the play area. If this cross warp has any post depositional component then successive sediment zero edges will be captured across the play area depicted. The individual prospect areas are drawn on the basis of at least arguable seismic evidence of an area of closure.

Objectives:
Sediments of the lower portion of the "infill" sequence onlap the "TU". This portion of the section has not been penetrated in the neighbouring exploration wells as it pinches out onto the Weaber structural high and onto the south eastern margin below the Spirit Hill-1 well. Similarly, it does not appear in outcrop on the Pincombe Inlier margin.

Seismic character suggests an interbedded sequence, possibly carbonates and clastics. It may conceivably include units of the Langfield Group, such as the Zimmerman Sandstone, Septimus
Limestone, and even the Enga Sandstone as defined in the outcrop of the synclinal "core" in the Burt Range area, and thus have considerable reservoir potential. However, the stratigraphic position of these outcrop units relative to the "TU" has not yet been established. The assignment of section in some exploration wells and mineral boreholes to these outcrop units should also be treated with caution.

Identification of specific reservoir objectives cannot therefore be made at this time. Intersections of the "Lower Milligans" interbedded sequence between 500 and 1500 metres should lie within the oil window.

WEAK LEAD NP6

Play Type: AC
Location: Between and in the vicinity of intersections of lines BR20 and BR18 with BR3.
Description: A north east plunging structural nose. Possible wedge out of section beneath the "TU" and/or pre-"TU" fault blocks sealed by shales overstepping the "TU".
Objectives: Pre-"TU" section of Tournaisian to Frasnian age, to 1500 metres, oil, or deeper gas.
Status and Work Recommendations: Good quality seismic required in order to establish a more specific potential trap.

WEAK LEAD NP7

Play Type: AB1.
Location: Between lines BR18 and BR16, generally south east of and in the vicinity of, BR5.
Description: A potential embayment play area on the basis of airphoto evidence and some poor quality seismic evidence.
Status and Work Recommendation: Good quality seismic required to delineate play.

WEAK LEAD NP8

Play Type: AA? AB? AC?
Location: Line BNT 80 - 205 around VP 420.
Description: A complex "build up" on a structural terrace. There is some possibility that structural closure may be present in this
area. Further seismic is required before this feature can be properly classified.

Status and Work Recommendation:
Detail seismic in this area should be considered if encouragement is gained from drilling elsewhere in the NP (Sorby) area.

**PLAY AREA NP9**

Play Type: AA, AB, AC.


Description: This play area covers the axial portion and the eastern flank of the NNE plunging Pincombe Trend. Existing seismic data quality is poor over most of the area. The axial portion could be prospective for type AB2 onlap plays as the attitude of the onlap edges cannot yet be determined. The possibility of shoaling basal sands to the onlapping Milligans sequence should also be considered. Type AB1 embayment plays are more likely to occur on the eastern flank (NP9b) along with type AC wedge outs beneath the "TU". There are also indications on the existing seismic of type AA build ups similar to prospect NP3.

NP9a is a possible small structural closure along the axial trend. It is doubtful that there is any section between the Milligans Formation and basement at this locality. It would, however, be an interesting location for a test of the reservoir quality of any Milligans Formation sands developed over this major structural trend.

Status and Work Recommendations:
Additional seismic could be considered over this area in conjunction with any additional work on NP3.

**WEAK LEAD NP10**

Play Type: AB1, AC.


Description: A potential embayment of post "TU" sediments similar to the NP5 play. However, the quality of the older vintage seismic is inadequate to establish capture of the zero edges to the south, thus the play remains fairly speculative at this stage. Wedge out of section beneath the "TU" onto the eastern margin is also possible in this area.

Objectives: As for NP5.

Status and Work Recommendations:
Review after drilling in the NP5 (Sorby) area.
PLAY AREA NB1

Play Type: AB, AC, and AA?

Location: Generally along the south eastern or Bundaberg portion of the margin tract.

Description: Conceptual play area based on features present on regional seismic lines 88-505, 88-514, 88-516 and 88-518. Sub-areas NB1A, C, E, G, I, and K, are identified as containing plunging structural noses on the basis of the seismic and/or airphoto evidence. These have potential for type AC and AB2 stratigraphic plays, and possibly for type AA structural closures (NB1E and NB1G in particular). Sub-areas NB1B, D, F, H, and J have potential for type AB1 embayment plays, on the same basis.

Objectives: Both pre- and post-"TU" sediments within the probable oil window from 500 to 1500 metres as described under the heading "Play Concepts".

Status and Work Recommendations:
Good quality semi detail seismic is required in order to firm up the prospective areas.

PLAY AREA NB2

Play Type: D, AC, AB.

Location: In the general area of intersection lines 88-514 and 88-505.

Description: NB2 is a continuation of play area NB1 but with additional features of interest. A large intrusive body is apparent on line 88-514 centered on VP 1260. This may well be a salt piercement feature, although an igneous intrusion cannot be ruled out at this stage. There are numerous features of interest on lines 88-514 and 88-505 in the vicinity of the intrusion. These include fault slices, stratigraphic pinchouts, and possible facies changes. NB2a appears to be a major nosing feature and its geometry to the north and north west warrants investigation. NB2b is a zone of stratigraphic interest with wedge-outs towards NB2a and NB2c suggested. There is potential for a wide variety of trapping situations in this area including structural closure at deep horizons.

Another interesting feature of the area is the easterly dipping well bedded sequence seen on 88-514 east of the intrusive body. There is no specific outcrop evidence to identify this sequence and it could be anything from Devonian to Proterozoic in age.

An oil "flow" was reported from a percussion drilled mineral borehole in the NB2 area. Unfortunately no further description is given, but as the well was drilled with water it seems reasonable to assume that a significant quantity of bitumen (biodegraded oil) globules were brought to the surface. The drilled lithology is described as calcareous siltstone but no age dating is given. From
the position of the borehole it is likely that the show originated in Tournaisian section. The significance of this show should not be overestimated, but it does confirm the continuation of the pattern of oil shows at the margin into the northern area of EP-31.

Objectives:
As for NB1, with potential for deeper gas? plays.

Status and Work Recommendation:
Good quality detail seismic required following gravity work on strong lead NB2c (see above).

WEAK LEAD NL2

Play Type: AA,CA,CB?,D.

Location: Line 88-514, VP 520 to 820.

Description:
A fairly subtle roll of about 30 ms. on an event which may possibly be the "TU" (VP 720, 740ms.). Unfortunately it is not possible to unequivocally tie back to line 516 via the faulted margin, and a much more prominent roll (VP 700 1400ms.) deeper in the section must also be considered a candidate for the "TU". The deeper event has a sequence onlapping its flanks as well as truncated sub-unconformity events, which are typical of the "TU". The deeper event could also be interpreted as a salt swell.

The shallower section also displays some seismic "activity" with events dipping away from a noise area around VP 580. The possibilities of a nearby salt intrusion and associated shallow oil plays cannot be discounted for this feature. A small amplitude anomaly also occurs (VP720, 450ms.) possibly on the upthrown side of a shallow fault and above the crestal region of the two deeper rolls.

Objectives:
"Subtle" oil plays to 750 metres. Oil or gas plays in presumably early Carboniferous section to 1400 metres. Oil or gas unconformity/carbonate build-up? at 1400 metres. Deep gas plays around 3500 metres.

Status and Work Recommendation:
Seismic semi-detail required as well as additional regional lines linking this area to NL1 along the possible structural trend.
PLAY AREA NL3

Play Type: AA, CA, CB, D.

Location: Bundaberg - Legune area. North west of and parallel to the south eastern basin margin.

Description:
A postulated structural high trend (Legune Trend) on the basis of reversals on lines 88-514 and 88-516, and possible south eastern dips at the north western end of 88-518.

Objectives: As for NL1 and NL2.

Status and Work Recommendations:
Additional regional lines to investigate the south western and north eastern limits of the trend, together with detail and semi-detail work on and between NL1 and NL2.
EP-126 AND APPLICATION AREA

PROSPECTS

PROSPECT WW1

Play Type: B1, B2.

Location: North west of intersection 88-412 and 87-303.

Description:
B1: 4 way dip closure on "TU" and exposed top carbonate. Approx. 150ms roll on 87-303, approx 600 ms roll on 88-412. Critical closure to the north west defined by dips measured in exposed limestone - no marker beds. Possible compressional "drape" fold over major fault block.

B2: Fault block beneath B1 dipping ENE. into the basin at approximately 25°. Bounded to the west by a down to the west fault of unknown throw but probably at least equal to the displacement of the west flank of the B1 fold. Bounded to the south by a down to the south fault of unknown throw together with truncation of the upper fault block section by the south dipping "TU" south of the south bounding fault. Dip closure to the east and north.

Estimated Closure:
Area: B1 - 750 acres, B2 - greater than 750 acres.
Vertical: B1 - 150 metres, B2 - greater than 150 metres.

Objectives:
B1: Basal Ningbing Group dolomites, at 500 to 1000 metres, oil. Late Frasnian sandstones (conjectural possibility of patch reefs), at 500 to 1500 metres, oil or gas.
B2: Frasnian, coarse grained sandstones, gas.

Status and Work Recommendation:
Immediately drillable as valuable stratigraphic location to investigate the Frasnian and basal Ningbing Group play and as a valid structural test. Additional seismic is not recommended as the karst terrain prohibits practicable seismic across the critical north west closure.

Possible Drill Locations:
88-412, VP 480, (or up to 100 metres NW of VP 480).
88-412, VP 414 (B2).

PROSPECT WW2

Play Type: AB1, AD.

Location: Largely south and south west of intersection 87-303 and 87-310.

Description: AB1: Embayment trap of onlapping "Lower Milligans" sequence. Zero edges climb to the south west from
87-303 to 87-310 forming north "flank" of embayment. High probability of "mirror image" south "flank" inferred from local outcrop geology. AD: Truncation of up to 400ms of ENE dipping section under the embayment by ESE dipping "TU". Extent of critical south closure not yet determined by seismic.

Closure:
Area: AB1: Of the order of 2500 acres "per zero edge" possible.
   AD: Of similar magnitude to AB1.
Vertical: AB1: Could possibly exceed 200 metres.
   AD: Could possibly exceed 400 metres.

Objectives:
AB1: "Lower Milligans" possible equivalents of upper Langfield Group, sandstones and dolomites at 800 to 1500 metres, oil.
AD: Frasnian to Tournaisian section at 1200 to 2000 metres, oil or gas.

Status and Work Recommendation:
Possibly immediately drillable as valuable stratigraphic location with very good stratigraphic trap potential. Alternatively define trap potential by seismic detailing extending into application area.

Possible Drill Locations:
87-310 VP154
87-310 VP222

PROSPECT WW3

Play Type: B1,B2?

Location: Southern Ningbing Range outcrop.

Description: B1: Complex of faulted domal closures mapped on outcropping limestone surface, partly by ground traverse and partly by airphoto interpretation. The western anticline is covered by ground traverses, and drag into its east bounding fault is clearly visible on the airphotos. Access into the area is difficult.
   B2: Conjectural only. By analogy with WW1 the folds could pass into a fault block at depth.

Estimated Closure:
Area: B1 - 500 acres.
Vertical: B1 - Probably less than 100 metres, possibly greater at depth.

Objectives:
   Late Frasnian sandstones (conjectural possibility of patch reefs), at 500 to 1500 metres, oil or gas.
B2: Frasnian, coarse grained sandstones, gas.
Status and Work Recommendation:
Could be considered as a possible slim hole location but access for all but a heli-rig could prove impossible. Portable (cord?) seismic may be possible over the limestone terrain, but the results would be likely to be indifferent to useless.

Possible Drill Locations:
Crestal.

PROSPECT WN1

Play Type: B1, B2?
Location: Southern Ningbing Range outcrop.
Description: B1: An area of potential closure suggested by airphoto and ground traverse work. An anticlinal trend is present but interpretation is hampered by faulting and poor outcrop of massive limestones.

   B2: Conjectural only. By analogy with WW1 the folds could pass into a fault block at depth.

Estimated Closure:
Area: B1 - 500 acres.
Vertical: B1 - Probably less than 100 metres, possibly greater at depth.

Objectives:
   Late Frasnian sandstones (conjectural possibility of patch reefs), at 800? to 1500? metres, oil or gas.
B2: Frasnian, coarse grained sandstones, gas.

Status and Work Recommendation:
Possible slim hole location in application area. Vehicular access may be possible, with some earthmoving assistance. Seismic acquisition is probably impractical. Further field mapping could be considered.

Possible Drill Locations:
Crestal

PROSPECT WN2

Play Type: B1, B2?
Location: Southern Ningbing Range outcrop.
Description: B1: As for WN1 this is an area of potential closure suggested by airphoto and ground traverse work. There appears to be a faulted anticline on trend with WW1 and en echelon to WN1, but the outcrop evidence is not definitive.

   B2: Conjectural only. By analogy with WW1 the folds could pass into a fault block at depth.

Estimated Closure:
Area: B1 - 500 acres.
Vertical: B1 - Probably less than 100 metres, possibly greater at depth.

Objectives:
B1: Basal Ningbing Group dolomites, at 600? to 1200? metres, oil. Late Frasnian sandstones (conjectural possibility of patch reefs), at 800? to 1500? metres, oil or gas.
B2: Frasnian, coarse grained sandstones, gas.

Status and Work Recommendation:
Possible slim hole location in application area. Vehicular access is probably impractical. Further field mapping could be considered.

Possible Drill Locations:
Crestal

PROSPECT WN4a

Play Type: "reef", AC, B?.

Location: Line 81-206, VP 123 to 136.

Description: WN4a is a small "reefal" anomaly on the "TU", similar to that on which Ningbing -1 was drilled. Top carbonate is at approximately 700 metres and a well on this anomaly could also possibly test a valid type AC play to at least 1200 metres. There is some evidence that the feature is located on a SSE plunging structure, but closure at depth would appear to need to rely on updip fault seal.

Estimated Closure:
"reef":
Area: Probably less than 200 acres.
Vertical: 50 metres?
AC: no data.

Objectives:
Late Tournaisian? reef? from 700 to 900 metres, oil.
Tournaisian? sands and carbonates from 900 to 1200+ metres, oil or gas.

Status and Work Recommendations:
Potential slim hole target on the border of EP126 and the application area. Alternatively, detail with one strike line.

Possible Drill Locations:
Line 81-206, VP 127.
PROSPECT WB1a

Play Type: AA2, AB2, AD, B.

Location: Line 88-428, VP 410 to 540.

Description: Rollover of about 50ms. into the margin fault, on an unconformity tentatively identified as the "FU". This occurs at the relatively shallow depth of 880 ms. on a probably south plunging structural trend. Critical closure to the NNW. is supported by line 80-103 but is not delineated by the existing seismic. Data on line 88-400 is extremely poor, but could be taken to indicate that the "FU" on the same structural trend is significantly higher on this line. However, if this is the case, then it appears that the immediately post-"FU" section wedges out up plunge to the NNW. (as well as against the margin fault to the west). This introduces the possibility of a substantial area of stratigraphic closure (WB1b) on this structural trend in addition to the possible structural closure. It is also possible that strong lead WB4 lies on the same structural trend.

In the shallower (Milligans Formation) section, roll into the margin fault is reduced to about 20 ms. but could extend along strike to line 88-400 (Lead WB1c).

Section beneath the "FU" is truncated by the "FU" and any reservoir within this section will be caught in a truncation trap if structural closure exists at the "FU". A wider ranging truncation trap independent of this closure could also speculatively be present. Deep structure is in the form of a broad "half anticline". The strong reflector at 1.7 sec. flattens, probably into the margin fault, but does not clearly roll. This deeper section could be prospective for gas if closure against the fault is effective.

Estimated Closure:
AA2, AB2:
Area: 1500 acres.
Vertical: up to 100 metres.

Objectives:
Sands within the Milligans Formation, possibly cleaning up towards the margin, to 1200 metres, oil.
Tournaisian sands, 1200? to 1800 metres, oil or gas.
Truncated section, 1800 to 2000 metres, gas, oil possible.

Status and Work Recommendations:
On balance, this prospect should probably be detailed before drilling. However the efficacy of further seismic acquisition in this difficult area can be weighed against the probability that either stratigraphic or structural closure, or both, does exist. The prospect could accordingly be considered for drilling at this stage.

Possible Drill Locations:
Line 88-428, VP 480, Conventional well to 2200 metres.
PROSPECT WB2a

Play Type: AA2, AD.

Location: Line 88-428, VP 640 to 750.

Description: A similar feature to WB1 but 100 to 200 ms. down dip (depending on the pick of the "FU"). Roll at the possible Tournaisian section is again about 50 ms. It is not possible to determine if this is reflected in the shallower Milligans Formation as the section is too noisy. The feature lacks deep potential structural closure, but a truncation play is possible at the "FU". Critical northward closure is well supported by a major arch on line 88-401 (at least 200 ms. of rollover), but the prospect lacks a crestal strike line for complete definition. The potential closed area is confined by apparently deeper section on line 80-100. Data is poor and unreliable however, and a larger potential closed area is outlined along the probable structural trend as play area WB2c.

Provided that the seismic correlations carried from the southern areas are at least roughly correct, WB2 should be prospective for oil in the Milligans Formation and possibly in the latest Tournaisian section. The major portion of the Tournaisian is more likely to be a wet gas prospect as is the truncation play.

The feature may be less favourably located than WB1 both in terms of depth to objectives and of favourable reservoir development.

Estimated Closure:
Area: at least 500 acres.
Vertical: 100 metres.

Objectives:
Sands within the Milligans Formation to 1400 metres?, oil. Sands within the Tournaisian section to 2200? metres, gas, possibly oil in the upper section. Section below the "FU" to 2400 metres, gas.

Status and Work Recommendation:
Detail seismic in conjunction with work on WB1, or drill as a gas play.

Possible Drill Locations:
Line 88-428, VP 695.

PROSPECT WT1

Play Type: CA, CB1, CB2.

Location: Crest around 88-401, VP 2420.

Description: A reversal of about 100 ms. at the early Tournaisian? level on strike line 88-401, with about 30 ms. rollovers on dip lines 88-402 and 88-404. This is essentially an up dip Bonaparte-1 structure and the potential for oil would appear to rest with the development of more, and cleaner, sands within the Milligans
Formation above 1600 metres. The prospects for oil would appear to be downgraded by the gas discovery in Bonaparte -2, although, of course, it has never been demonstrated that there is not an oil leg to the gas sand at 1439 metres in Bonaparte -2.

Below 1.8 sec. a major unconformity truncates deeper section. This is probably the unconformity identified as "FU" at prospect WB1 at a much shallower depth, and indeed WB1 and WT1 may lie on the same structural trend. If Frasnian sands are present below the "FU", then WT1 is a good deep gas prospect.

There appears to be an extension to this prospect, or a separate lead, around intersection 88-404, 80-105 (WT1b), at least at the shallower levels. Correlation into this area is uncertain.

Estimated Closure:
Area: 1750 acres, or 2750 with WT1b.
Vertical: 100 metres.

Objectives:
Sands within the Milligans and Tanmurra Formations to 2000 metres, gas or oil. Tournaisian sands from 200? to 2800? metres, gas. Frasnian sands from 3600? metres, gas.

Status and Work Recommendation:
A drillable conventional gas prospect, with some chance of oil.

Possible Drill Locations:
Intersection 88-402, 88-401.

PROSPECT WT3

Play Type: CA, CB1, D?

Location: Line 88-401, VP 2750 to 3250.
Line 88-408, VP 500 to 660.

Description: This prospect lies up dip from the Bonaparte -2 gas discovery which appears to have been made outside structural closure. The feature is probably a simple roll into the margin, but both the upper and deeper section appears to be cut up by faulting. This is also a bad data zone and the presence of a landsat circular anomaly (WT3b) could be indicative of salt piercement. On the basis of the Bonaparte discovery, WT3 would appear to be primarily a gas prospect. The deeper and presumably water saturated sands in Bonaparte -2 could be gas productive over this prospect area. The possibility of an oil leg to any gas sands cannot be ruled out.

Estimated Closure:
Area: 2000 acres.
Vertical: 100? metres.

Objectives:
Early Visean sands to 2000 metres, gas, chance of oil. Tournaisian sands to 2800 metres, gas.

Status and Work Recommendation:
Reprocess 88 seismic and attempt to "clean up" the interpretation. Add WT3b feature to detail gravity survey. Add to inventory of drillable gas prospects if then warranted.

Possible Drill Locations:
Line 88-401, VP 3205.

PROSPECT WR1b

Play Type: AA2, AB1, CB?.
Location: Redbank area, north of Jeremiah Hills.

Description:
WR1b: Possibly small closure on roll into the margin. Closure does not appear to be likely to exceed 10ms. at the "Tournaisian sands" level, but even this small structural closure enhances the type AB1 stratigraphic play. There is also high risk possibility of a deep gas play at this prospect. Deeper strata including Frasnian? sands may be involved in subthrust structural closure.

Estimated Closure:
Area: 250 acres.
Vertical: 20 metres.

Objectives:
Early Visean and Tournaisian sandstones, from 600 to 1600 metres, oil. Tournaisian? sands below 1600 metres, gas.

Status and Work Recommendation:
Re-evaluate at end of slim hole drilling project on other prospects. Potential deep slim hole location to 1800 metres, or conventional test to 2200 metres or to 3400 metres.

Possible Drill Locations:
Intersection 88-407.
STRONG LEADS

STRONG LEAD WW4

Play Type: B1, B2?

Location: Southern Ningbing Range outcrop.

Description: B1: Moderate relief faulted anticline, with a short north plunge, at the southern edge of the Ningbing Range. Conjectural reversal of plunge to the south, or closure at a down to the south fault, into the "Waggon Graben".

B2: Conjectural only as for WW3.

Estimated Closure:
Area: B1 - 500 acres.
Vertical: B1 - 100? metres.

Objectives:
B1: Basal Ningbing Group dolomites should be at shallow depth. Probably Frasnian objectives only in as yet undrilled section.

Status and Work Recommendation:
Could warrant seismic coverage south of the outcrop area as closure could be considerably larger than the outcropping portion suggests. If so, the resulting prospect would be a convenient target for exploration of the Frasnian section.

STRONG LEAD WN3

Play Type: B1, B2?

Location: Central Ningbing Range outcrop.

Description: B1: An area of potential closure suggested by airphoto and ground traverse work. A high relief anticlinal trend is present but closure to the north west is questionable.

B2: Conjectural only. By analogy with WW1 the folds could pass into a fault block at depth.

Estimated Closure:
Area: B1 - 250 acres.
Vertical: B1 - Possibly greater than 100 metres depending on critical closure.

Objectives:
B1: Basal Ningbing Group dolomites, at 200? to 800? metres, oil. Late Frasnian sandstones (conjectural possibility of patch reefs), at 300? to 1000? metres, oil or gas.
B2: Frasnian, coarse grained sandstones, gas.

Status and Work Recommendation:
Possible very high risk slim hole location in application area. Vehicular access may be possible, with some earthmoving assistance. Seismic acquisition is probably impractical.

Possible Drill Locations:
Crestal
STRONG LEAD WB2b

Play Type: AA2, AD?, D?.

Location: Line 88-400, VP 550 to 710.

Description: A similar feature to WB2 and probably on the same structural trend but a little deeper. Data is extremely poor on 88-400 and whereas the reversal is relatively clear in the shallow section, the situation near the "FU" must be largely inferred. WB2 is adjacent to a very noisy zone at the northern end of 88-401 and could thus be related to a salt feature (see lead WB7).

Estimated Closure:
Area: 500? acres.
Vertical: 100? metres.

Objectives:
As for WB2

Status and Work Recommendation:
Reprocess 88-400, detail in conjunction with WB2 if encouraging.

STRONG LEAD WB4

Play Type: AA3, B?.

Location: Near King Gordon Spring north of the Ningbing Range.

Description: A possible slim hole prospect based on outcrop. A "sliver" of limestone dips westward at around 25°. The limestone outcrop is about 50 metres wide (strike) and 750 metres long (dip) representing about 300 metres of section. The age of this carbonate is not known, and it may be anything from early Famennian to early Visean. It is inferred that this feature represents a structurally high fault block as it lies at the eastern edge of the extrapolated strike of the Ningbing carbonates and is surrounded by presumably younger sandstones.

It is conceivable that this feature is an upfaulted and up plunge extension of the WB1 structural trend, or an en echelon repetition of this trend.

Status and Work Recommendation:
This feature should be investigated at least with one seismic dip line passing to its north. A location at the eastern edge of the outcrop could also be added to an inventory of possible slim hole locations, as a well here would provide a valuable "index" to the section as well as having a reasonable chance of being on structure.
STRONG LEAD WB6

Play Type: B.

Location: Knob Peak area, west of Ningbing range.

Description: Small moderate relief surface anticline with possible Cockatoo Group sandstone exposed in the core. North west closure is suggested by the outcrop pattern only. The feature is about 3 km south of a reported bitumen show in a mineral bore hole west of the Ningbing Range.

Estimated Closure:
Area: 250 acres.
Vertical: 50? metres.

Objectives:
Frasnian section only, would rely on intraformational seal.

Status and Work Recommendation:
Investigate in conjunction with base metal exploration.

STRONG LEAD WB7

Play Type: D.

Location: Line 88-400, VP 760 to 820.

Description:
A data drop-out underlying a circular landsat feature which could thus conceivably represent a salt piercement. It should be stated that there is no definitive evidence for a salt feature visible on the seismic section. If it is a salt feature then adjacent leads WB3 and WB2b are likely to be related to it.

Status and Work Recommendation:
Investigate with a detail gravity grid. A seismic line at the edge of the tidal flats, passing to the north of the landsat feature is also recommended.

STRONG LEAD WT2

Play Type: D.

Location: Line 88-401, VP 2070 to 2250.

Description: A reversal of about 100 ms. on line 88-401 at an early Tournaisian level? The form of the reversal together with the very poor data in this zone is suggestive of a non piercement salt swell adjacent to WT1. The feature could also be seen as a simple structural lead similar to, and slightly deeper than, WT1.

Estimated Closure:
Area: 750? acres.
Vertical: 100? metres.
Objectives:
As for WT1 if not a salt feature.

Status and Work Recommendation:
Include in detail gravity grid.

**STRONG LEAD WT5a**

Play Type: B.

Location: Within the Ningbing Range, Tanmurra area.

Description: Moderate relief surface anticline confirmed by ground traverses. Critical closure to the north is not fully mapped out but probably exists.

Estimated Closure:
Area: 250 acres.
Vertical: 50? metres.

Objectives:
Basal Famennian dolomites at 300? metres, oil. Frasnian sands below 300? metres, oil or gas.

Status and Work Recommendation:
Investigate in conjunction with base metal exploration?
Possible slim hole target.

**STRONG LEAD WR1a**

Play Type: AB1.

Location: Redbank area, north of Jeremiah Hills.

Description:
Embayment of post "TU" section. Zero edges climb into the north plunging "Jeremiah Syncline". Similar to prospect WW2. Only the eastern "limb" of WR1a is defined by seismic. The western "limb", connecting with WW2, is inferred from the outcrop geology. Unlike WW2, no obvious truncation of pre "TU" section is seen.

Estimated Closure:
Area: up to 2500 acres.
Vertical: up to 200? metres.

Objectives:
Early Visean and Tournaisian sandstones, from 600 to 1600 metres, oil.

Status and Work Recommendation:
Either improve seismic coverage or re-evaluate after drilling of WR1b.
WEAK LEADS AND PLAY AREAS

WEAK LEAD WW5

Play Type: CA, CB1

Location: South western "corner" of the Weaber Range.

Description: Some airphoto evidence of a slight roll or step fault in the shallow section. Some "flattening" at east end of nearby line 87-310. Possibly connected with subtle (20ms.) rolls on lines 88-414 and 88-412 and a 40ms. roll on 88-403.

Estimated Closure:
Area: Up to 2000 acres.
Vertical: Up to 100 metres.

Objectives:
Sands in "upper" Milligans Formation, follow up of oil shows in Garimala -1, 400? to 1000? metres. Sands in "lower" Milligans sequence 800? to 1500 metres, oil.

Status and Work Recommendations:
A good structural lead area warranting seismic semi-detailing, either in conjunction with detailing of WW2 or after drilling of WW2. Access into the valleys will have to be utilized in order to avoid the escarpment area of the Weaber Range.

PLAY AREA WW6

Play Type: AB1, AC, AA2.


Description: An area with moderate stratigraphic entrapment potential. WW6a is a potential embayment area for type AB1 traps, based on outcrop patterns and the reversal on 87-303. WW6b is a minor roll into the margin seen on 88-306, VP 164 to 190. This could be a post depositional fault/fold feature. If it extends to the north it could enhance the embayment trap. WW6c is a structurally nosing area. There seems to be little potential for a type AB1 play as the zero edges climb toward the WW2 prospect. The potential for type AC plays is also confused by truncation of the pre "TU" sediments in a southerly direction (line 87-303).

Objectives:
Early Visean shore face sands from 600 to 1400 metres, oil.
Tournaisian sands and carbonates from 600 to 2000 metres, oil or gas.

Status and Work Recommendations:
This area should be reassessed after drilling on WW1 and WW2.
PLAY AREA WN4

Play Type: AB1, AB2?, AC, and "reef".

Location: The margin tract, north and south of the Ningbing -1 well.

Description: See also WT4 and WB5. South of Ningbing -1 post "TU" zero edges are relatively horizontal thus substantial AB1 or AB2 traps are unlikely in the absence of lateral stratigraphic variations. The zero edges appear to rise towards WN4c and a substantial embayment could be present, although present seismic control is limited. The outcrop pattern also suggests potential for nosing in the north of this area and type AB2 and fault dependant type AC traps are a possibility. WN4b is similarly a nosing area. This is up dip from the Ningbing -1 oil show, and if the basal sand in this well is in fact Tournaisian and not Frasnian, then an up dip type AC trap is a real possibility.

It should be noted that sands from about 250 metres to 1000 metres in Ningbing -1 were gas saturated. This could be taken to indicate either that a very substantial type AB1 trap is present, or merely that the sands are lenticular. It would certainly be desirable to test the down dip liquids potential of any well developed shallow gas saturated sand in the Milligans Formation.

Objectives:
Early Visean shore face sands from 700? to 1500 metres, oil.
Tournaisian sands and carbonates from 700? to 2000 metres, oil or gas.

Status and Work Recommendations:
Additional detail seismic could be considered for this area if it was felt that a significant improvement in data quality could be achieved.

WEAK LEAD WB3

Play Type: CA, CB?, AD?

Location: Line 88-400, VP 820 to 1020

Description: As with WB2b, this is a gentle roll into feature WB7, but this time basinward of the suspected salt feature. The roll is definable only in the shallow section, the data at depth being unusable. The shallow section at WB3 actually appears to be about 100ms. higher than at WB2c. If any reservoir is developed in the Milligans Formation, or if the Tamurra Formation is sealed, then WB3 could mature into a small shallow type C oil prospect.

Estimated Closure:
Area: 500? acres.
Vertical: 50? metres.

Objectives:
Sands within the Milligans and Tanmurra Formations to 1400 metres?, oil. Possibly deeper objectives.

Status and Work Recommendation:
Reprocess 88-400, detail seismic along with other WB leads.

**PLAY AREA WB5**

Play Type: AB1, AB2, AC, AA2, B?.

Location: Western ends of lines 88-400, 88-428, and 88-426.

Description: An area of considerable stratigraphic play interest. Onlapping zero edges rise from the Tanmurra area and an embayment play (AB1) is possible around line 88-426. The onlap pinchouts may also be picked up by later cross faults forming an AB1 play, eg. at 88-428, VP 240 to 350. Line 88-426, VP 300 to 460 could be regarded as a "type section" for the AC stratigraphic wedge beneath the "TU". This play is enhanced by a 20 ms. reversal in presumably Tournaisian section below 800 ms. (AA2). A 50 ms. reversal at a strong event at 1.5 sec, if not spurious, may be regarded as a type B Frasnian lead. The structural elements of this play area are designated Lead WB5b.

Objectives:
Early Visean shore face sands from 600 to 1400 metres, oil.
Tournaisian sands and carbonates from 1000 to 2000 metres, oil or gas.
Frasnian sands? from 3600 metres, gas.

Status and Work Recommendations:
The area warrants at least additional seismic in conjunction with the WB1 and WB2 prospects.
WB5b is a potential deep slim hole target to 2000 metres, as a well in this location would greatly assist the evaluation of the basinward prospects, whilst itself having a reasonable probability of validly testing a stratigraphic or structural play, or both.

Possible Drill Locations:
Line 88-426 VP 362.

**PLAY AREA WB8**


Description: Unexplored area on strike with the Brolga prospects and leads.

Status and Work Recommendation:
A reconnaissance seismic survey consisting of at least one strike and two dip lines is recommended. The positioning of the lines and timing of the survey will be constrained by the tidal flats and
tidal channels and environmentally sensitive wetlands. An existing vehicle track runs to the coast through this area. Examination of the offshore seismic data may assist in the design of this survey.

**WEAK LEAD WB9**

Play Type: CA? CB? D?

Location:
In relinquished area to the east of the Brolga area.

Description:
A very subtle topographic high within the area of the tidal flats. It is suspected that this could be the surface expression of a salt related feature.

Status and Work Recommendations:
This feature will be investigated by detail gravity, and provisionally by seismic, as part of a separate salt exploration program. If the results of the detail gravity are available in time, they may influence a decision to re-apply for the relinquished portion of EP 126.

**PLAY AREA WT4**

Play Type: AB1, AB2, AC.

Location: The margin tract, up dip of the Bonaparte wells.

Description: An area analogous to WB5 but poorly covered with usable seismic. Outcrop patterns suggest that both nosing and embayment trends should be present, but there is no evidence of enhancing structural features. At this stage it would appear to be preferable to initially approach these plays in the Brolga and Waggon Areas.

Objectives:
Early Visean shore face sands from 400? to 1500 metres, oil.
Tournaisian sands and carbonates from 800? to 2000 metres, oil or gas.

Status and Work Recommendations:
Place this area on "hold" until encouragement is obtained from other stratigraphic play areas.

**WEAK LEAD WT5b**

Play Type: B.

Location: Within the Ningbing Range, Tanmurra area.

Description: Moderate relief surface anticline only partly confirmed by ground traverses. Critical closure to the north is questionable and could rely on down to the north cross faulting

Estimated Closure:
Area: 550? acres.
Vertical: 50? metres.

Objectives:
Basal Famennian dolomites at 300? metres, oil. Frasnian sands below 300? metres, oil or gas.

Status and Work Recommendation:
Investigate in conjunction with base metal exploration?

WEAK LEADS WR1c and WR1d

Play Type: AC.
Location: Redbank area, north of Jeremiah Hills.

Description:
This is an area of potential stratigraphic pinchouts of Tournaisian reservoir units beneath the "TU". The play is highly conjectural at this stage, and it will be necessary to first drill the section before the play can be properly delineated. There appears to be additional potential in WR1c for "subthrust" closures against high angle reverse faults under the "TU".

Objectives:
Tournaisian sandstones and dolomites?, from 400 to 1600 metres, oil.

Status and Work Recommendation:
It may require purely stratigraphic drilling in up dip locations to establish this play.

WEAK LEAD WR2

Play Type: AA?, AC, B?.
Location: Eastern Redbank area, Oakes Horst Trend.

Description: Seismic definition is poor, but probable Tournaisian section appears to drape over a NNE. plunging high trend. Up dip closure for any plays will require either cross faulting or stratigraphic control. Type AC pinch-outs are conceptually possible, and type AA "build ups" could conceivably be present.

Objectives:
Tournaisian to Frasnian section to 1500 metres, oil.
Famennian? and older section below 1500 metres, gas.

Status and Work Recommendation:
Although data quality on line 88-314 is disappointing, additional seismic in this area could be considered. A slim hole on a location such as 87-305, VP 370, would provide a valuable reference to the section and would seem to have some chance of testing a fault or stratigraphic closure.
PLAY AREA WR3

Play Type: AB1, AA?, AC?

Location:
South western portion of EP-126.

Description:
WR3 covers the western flank of the NNE plunging Pincombe Trend (WR3a) and the synclinal area between this and the Oakes Horst Trend (WR3b). There is little seismic coverage of the area and access is limited by the escarpment of the Weaber Range. Type AC plays and AA structures could conceivably be present over WR3a, whereas WR3b is conceptually more favourable for type AB1 embayments.

Status and Work Recommendations:
Hold for re-evaluation after drilling elsewhere.

WEAK LEADS WM1 AND WM2

Play Type: CA?, CB?.

Location:

Description:
One line weak leads seen on lines N1 and 1A.

Status and Work Recommendations:
Re-evaluate if seismic acquisition in the basinal areas is being considered at a later date.
REFERENCES CITED


Le Blanc, M.C., 1964, Bonaparte No. 1 well completion report: Alliance Oil Development Australia N.L., unpub.


The report has been prepared at the request of Comada Energy Limited and is intended to provide a basis for continuing exploration in EP 126 (WA.) and EP 31 (NT.) and any adjoining onshore area in which Comada may gain an interest. Whilst it is a conclusion of this report that the above areas have ample oil and gas prospectivity to justify the continuation of exploration, nothing in this report should be taken to imply knowledge of the existence of commercial accumulations of oil or gas.

Respectfully Submitted
J. Gausden & Associates Pty Ltd
April 1989.

John Gausden BSc., FAusIMM, MMICA, MAAPG.
Director.
APPENDIX 1

SELECTED SEISMIC SECTIONS

SOUTHERN BASIN MARGIN EP31
WEST FLANK OF PINCOMBE TREND
SORBY AREA

PROSPECT NP1
WEAK LEAD NP5c

PINCOMBE INLIER

MILLIGANS FM
CA
AB1
AA1
AD
AA2
L
BURT RANGE FM
BUTTONS FM
CB2
COCKATOO GROUPT

SECTION 2
WESTERN BASIN MARGIN  EP126
WAGGON AREA

STRATIGRAPHIC PROSPECT WW2.

MILLIGANS FM
AD
COCKATOO GROUP
AB1
'LOWER MILLIGANS'
AD
TUE