BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Oligocene Epoch Pilot Study

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SUMMARY

In 1979 a small group of geologists in the Geological Branch was assigned the task of undertaking a pilot study of the Oligocene Epoch, with the objective of developing a satisfactory method of studying a geological period Australia-wide. The partly completed study was terminated in 1982, and this record describes the problems encountered.

It is recommended that steps be taken to improve the quality of data companies are required to lodge with BMR, that companies be required to supply microfiche copies of completion reports in addition to the hard copy reports submitted at present, that existing reports held in BMR be copied on to microfiche in batches beginning with the most recent, and that period studies should be full-time projects.

The study resulted in the preparation of isopach maps at 1:2.5 million scale of Oligocene rocks in the Bass and Gippsland Basins.

OLIGOCENE EPOCH PILOT STUDY

INTRODUCTION

In 1976, the Geological Branch Chief, noting that the program of 1:250 000 scale regional mapping was nearing completion, proposed that the branch begin a program of Australia-wide studies of geological periods i.e. studies of the palaeogeographic evolution of the continent during selected time intervals.

The advantages of such studies are: i) they provide the opportunity to present a continent-wide overview, an activity which can be undertaken by BMR more readily than can be done by state surveys, ii) relatively inexpensive (no, or little fieldwork), iii) in accord with many IGCP commitments and projects, iv) vital to resource assessment, v) valuable in pointing out weaknesses in knowledge.

The broad objective was to assemble, synthesize, interpret and publish Australia-wide information on rocks formed during a particular period of time with particular emphasis on their mineral content.

After some discussion within the Branch it was decided to begin by attempting a continent-wide study of the Oligocene epoch, with the aims of arriving at a satisfactory method of investigating a geological Period. The reason for choosing the Oligocene was that the interval was considered to be represented only to a limited extent in Australia, particularly onshore, so that a pilot study would not be overwhelmed with data. Also it was an eventful interval, characterized by rapid climatic events, and, geologically, by a number of unconformities, at least in the marine realm.

Because the Bureau is the designated authority under the Petroleum (Submerged Lands) Act for the custody of information from exploratory drilling offshore, it was envisaged that there would be no problem in obtaining offshore well data; hence the study would involve a minimum of consultation with outside agencies and therefore the proposed pilot study was expected to be completed relatively quickly.

The pilot study was included in the 1979 Sedimentary Section program. It was scheduled as a part-time task for six geoscientists with the Branch, with assistance from the Geophysics Branch (palaeomagnetics and marine seismic) and Operations Branch (ADP Group and Library).

Unfortunately owing to the pressure of high priority work on several of the compilers, only part of the study had been finished by late in 1981; it was decided at the program meeting in December that year not to proceed with further compilation of data, but to terminate the project with a report outlining the methods employed and the problems encountered. At that time, data from the Gippsland, Bass, and Murray Basins, Tasmania, and the Arafura Sea area had been compiled, nearly all derived from petroleum exploration wells.

PREVIOUS SIMILAR STUDIES

Previous nation-wide studies concerned with the rocks associated with particular geological time intervals are not numerous. The best documented in English are the maps and reports of the United States Geological Survey which describe 5 systems within the conterminous United States: Jurassic (McKee & others, 1956), Triassic (McKee & others, 1959), Permian (McKee, Oriel & others, 1967a & b), Pennsylvanian (McKee, Crosby & others, 1975) and Mississippian (Craig & Connor, 1979).

A more synoptic treatment with a petroleum exploration bias is presented by the exploration department of the Shell Oil Company Houston, Texas in their Stratigraphic Atlas of North and Central America (Cook & Bally, 1975).

A Palaeogeographical Atlas (Wills, 1951) deals with Britain and Europe at a small scale, whereas Schott (1969) describes in detail (in German) the palaeogeography of the Lower Cretaceous rocks of northwest Germany.

The Russians also have compiled palaeogeographic and palaeotectonic maps of the USSR at small scales together with explanatory texts in Russian (Vinogradov, 1969).

The references quoted above were consulted to gain an understanding of the objectives of the studies, the principles upon which the maps are based, and the compilation methods adopted; the following notes cover these aspects.

USGS The objective of the USGS studies is "to provide in graphic form the factual basis for recognition of tectonic events on a countrywide scale. The maps...depict rock thickness, generalized lithology, ancient geography, and other regional relations of the (Pennsylvanian) System" (McKee, 1975, p.1).

The principles upon which the System subdivisions are based and on which the lithofacies-thickness maps depend, are set out clearly by Oriel in the study of the Triassic System (*in* McKee et al., 1959, p.5) from which the following extracts are taken.
"To be useful as a tool for recognition of ancient tectonic events, distinctive rock units depicted for a given region...must bear some relation to those in other regions. Approximate continuity is a preferred relation. Ideally, then, subdivisions of each system should also be time-stratigraphic units recording individual major events. Unfortunately, from this standpoint a large majority of rock units represented in either measured surface sections or well-bore sections are not precisely dated. For this reason, attempts to project isochronous surfaces into these sections involve little more than the subjective guesses of individual stratigraphers, guesses that are not in general agreement.

If the palaeotectonic maps are to have permanent value, they must approach objectivity and reproducibility. They can do so only if the stratigraphic subdivisions that they portray are distinct physical units that can be recognized easily by other geologists. The subdivisions that are most likely to be reproducible - that is, measured in similar ways with similar results by several geologists - are rock-stratigraphic units. From this point of view then, the stratigraphic boundaries preferred are abrupt vertical changes in lithology.

Conspicuous lithologic changes in local sections...in most places do not correspond precisely to significant horizons in the world-wide arbitrary time scale...In the absence of abundant precise dates, however, abrupt vertical changes in lithology, either local or widespread, are likely to be useful as boundary markers for most geologists...

Objective summation of lithofacies and thickness data...has required the use of operational subdivisions that differ from currently recognized and named rock-stratigraphic or time-stratigraphic units. Use of interval subdivisions is a purely practical, old and informal technique in which the units chosen depend entirely on the purpose and scale of maps, on which they are depicted. Interval subdivisions may be of supraformational or subformational dimensions; they may correspond to a series, to a part of a series, to several series, or to parts of adjacent series. A given interval may, for convenience, include a formation (or other rock unit) that is correlative with rocks of more than one interval...Conversely it may exclude a formation whose rocks are correlative, in part, with rocks included in the interval. The word interval is preferred over other available terms because it has not been used in a specific sense by stratigraphers. Moreover, its retention as an unrestricted and general term is desirable for discussion of a sequence of rocks, time, or genetic events.

...Each (interval) contains a widespread, in places moderately thick, sequence of rocks genetically associated with or dominated by a major event in sedimentation."

In the Triassic study (Oriel <u>in</u> McKee et al., 1959, p.5) the system is subdivided into three parts, and for each part a combined lithofacies-thickness map portrays location and extent of sedimentary basins, thicknesses of deposits, and proportions of various sedimentary rock types. The assignment of rocks to the adopted intervals was based largely on a Triassic correlation chart of the Committee on Stratigraphy of the National Research Council.

A table lists the Triassic Formations of the US (in alphabetical order) the purpose being to enable the reader to ascertain the interval to which each formation is assigned, thus indicating the map or maps on which its lithology and thickness are shown. The table also shows the area in which each formation is known to occur.

A generalized correlation chart shows relative stratigraphic positions of Triassic formations within columns, each of which is made for a large area (e.g. Idaho, Wyoming, Montana SW, central, SE). Formations are arranged in horizontal rows corresponding to the three adopted intervals which are shown down the left-hand side of the chart; the European Stage names are shown down the right-hand side. Informal stratigraphic names are shown in italics.

Stratigraphic data have been summarized on manual sorting edge-punch cards; a punch card was made for each formation or interval at each locality or for the entire system at that locality. "The thousands of cards accumulated...form a permanent readily usable file of stratigraphic data arranged by State," (McKee et al., 1959, p.1).

An index to localities and sources of data for each study is provided. Each State has an independent series of index numbers the locations of which are shown on a map (1:2 500 000 scale in 4 sheets for Pennsylvanian study). These numbers refer to outcrop sections, well sections or composite sections. The purposes of the map of control points and index are "to enable the reader to (1) compare data used in the preparation (of the paper) with data from other sources, (2) compare data in the paper with those in other palaeotectonic investigations, (3) evaluate the relative significance and reliability of various parts of the maps and (4) prepare comparable but more detailed maps of local areas by the addition of supplementary data" (McKee et al., 1975, p.3).

Maps include a palaeogeological map showing the distribution of rock units at the surface upon which the sediments of the system were deposited, a map showing the units that now directly overlie the system, a summary isopach map indicating the total thickness of the system, maps indicating thickness for each of the intervals into which the system is divided and maps showing lithofacies for each interval. In addition there are cross-sections in selected areas. These dominantly factual maps are mostly at 1:5 million scale. Also included are interpretive maps based largely on data derived from the factual maps.

Shell Oil Company, Houston Texas

Since World War II the staff had been documenting geological data on a basin-by-basin format, utilising material from the company's exploration activities in almost every part of USA and Canada; in 1969 they began compiling the atlas using the basin summaries as the primary data bank, the purpose being to ensure that Shell scientists had at their disposal all of the background data regarding the stratigraphy of the continent contained in the company files (Cook & Bally, 1975).

Included for each unit are maps depicting the underlying stratigraphy, the geographic location of radiometric dates which fall approximately within the time span, location of hydrocarbons within reservoirs correlated to the unit, and a listing of references used to construct the map. The choice of map units (layers) was based largely on standard stratigraphic subdivisions, but was modified in places because some divisions were more widely mappable with confidence. The scale of the maps is 1:25 000 000.

Generally within each major subdivision there is first an outcrop map and a table of stratigraphic columns, thus defining the units mapped. Then follows the sub-crop map depicting the stratigraphic unit beneath the lowest portion of the unit present.

Isopach and lithofacies maps of various sub-units are positioned so that they face one another. The location of stratigraphic columns is shown by number on the isopach map, as are the location of cross sections. The cross sections are schematic and drawn from a horizontal datum depicting the top of the unit mapped.

USSR

The maps are in four loose-leaf volumes; 1. Precambrian, Cambrian, Ordovician and Silurian; 2. Devonian, Carboniferous and Permian; 3. Triassic, Jurassic and Cretaceous; 4. Paleogene, Neogene and Quaternary. Four volumes of explanatory text corresponding to the four map volumes were published in 1974. The following notes are taken from an English annotation included in the map volumes.

"In 1960-1966 the Ministry of Geology...and the Academy of Sciences of the USSR with contribution of some other organizations (Ministries of High Education, of Petroleum and Gas Industries etc) compiled an Atlas for the territory of the USSR containing lithological-paleogeographical and paleotectonic maps on a scale 1:7 500 000, a few maps on a scale 1:15 000 000 and some maps on different scales, which characterize the conditions of accumulation of some economic minerals of sedimentary origin and environment (of) sedimentation, etc. ...

The...Atlas presents a first essay of systematic cartographic representation of the physico-geographic conditions and the distribution of the main types of sediments and volcanic rocks on the whole territory of the USSR for different geologic periods, epochs and ages beginning from the Early Proterozoic (until) the (present) geologic epoch.

On lithological-paleogeographical maps there are shown in colours the geographical environments; seas of various depth, plains and highlands; with dashed lines - the sediments accumulated during a corresponding period of time in the regions of accumulation, and probable types of rocks eroded during this time in the regions of erosion. The accumulated volcanic formations and probable localities of volcanoes of central and fissure types are designated with red and coloured symbols. Isopachs of the total thickness of the sedimentary and volcanogenic rocks formed during a corresponding period of time are shown with blue lines. Moreover, there is given a scheme of biogeographical zonation for this time, showing zoo- and phyto-geographical regions and provinces, where the most important families and genera of fauna and flora for these provinces are indicated with letters.

The sites of concentration of economic minerals formed during corresponding periods of time are shown with special symbols. On paleotectonic maps regions of different tectonic regimes compiled for different stages of the tectonic evolution of the territory of the USSR are shown with colours, and inside them the types of accumulated sedimentary and volcanic formations are shown with dashed lines; their thickness is shown with isopachs; plutonic formations, and deep faults active during the given stage are shown by red lines.

In the compilation of the maps there were used general correlative stratigraphic schemes worked out by the Interdepartmental Stratigraphic Committee of the USSR...

The Atlas as a whole for the first time gives a complete presentation of the geologic history of all the territory of the Soviet Union and of the conditions of the accumulation of some important types of mineral deposits of sedimentary origin."

<u>UK & Europe</u>

The palaeogeographical atlas (Wills, 1951) contains twenty-two small-scale maps (e.g. 1:7 million, 1:5 million) of Britain and Europe. The treatment is general; no information is given about methods, only references on which the maps are based e.g. Jurassic maps are based on Arkell (1931), "The Jurassic System in Britain", and a few spot thicknesses of sediments are shown. Some isopachs are shown on the Upper Carboniferous map but generally thickness information is lacking. A revision of Wills atlas is underway (1982).

West Germany

The "Palaeogeographic Atlas of the Lower Cretaceous of Northwest Germany: (Schott, 1969) consists of two loose-leaf volumes of maps and a separate explanatory text. The first volume of maps contains 289 maps at 1:200 000 scale, and the second volume 10 maps and one overlay at 1:500 000 scale, 6 outline maps of north-central Europe at 1:1 500 000 scale and one stratigraphic table. The text is in German, and the following notes are taken from the English summary.

"The maps deal with the Lower Cretaceous epicontinental basin of Northwest Germany and its adjacent areas. Thickness, facies and palaeogeology of the various stages of the Lower Cretaceous in Northwest Germany are treated on the scales 1:200 000 and 1:500 000; with the help of a general representation of the northern part of Central Europe on the basis of the literature available it is intended to put the results obtained in NW Germany into a major framework. The explanatory text refers to form, genesis and relations of the various elements in this area of sedimentation. The treatment of NW Germany has been based on drillings and data of seismic reflection, which, owing to the intensive exploration (for) petroleum, natural gas, iron ore, potash, coal etc, are available to an unusually large extent."

METHOD OF STUDY

The plan was to extract data on the Oligocene Epoch contained in petroleum exploration completion reports and published geological literature; to enter these data into a machine readable system to manipulate and combine data following the general scheme described by USGS workers in an unpublished "Manual for compiling paleotectonic reports"; (the BMR "Manual for compiling basin study reports in the Petroleum Exploration Branch" is virtually the same, except for the inclusion of a chapter on geophysics, a geophysical glossary and an Appendix containing instructions for preparing reduced scale seismic cross-sections); to plot well and outcrop section locations of 1:500 000 scale maps, and to compile maps at this scale showing i) structure contours on the base and top of the Oligocene section, ii) thickness and lithology of the Oligocene section, iii) lithology of the surface on which the Oligocene rocks rest, and iv) lithology of the rocks overlying the Oligocene section; to reduce these 1:500 000 scale compilations to a final map scale of 1:2.5 million and prepare a report to accompany these maps.

Oligocene rocks are known in many Australian sedimentary basins and elsewhere, so at the start of the project particular areas of responsibility were decided upon for each participant. These areas were (Figure 1):

1. Offshore northwest Australia, Beagle Sub-Basin, Browse Basin, Bonaparte Gulf Basin, Capricorn Basin;
2. Bass and Otway Basins;
3. Murray, St Vincent and Eucla Basins;
4. Carnarvon and Perth Basins;
5. Gippsland Basin, Tasmania, Arafura Sea area;
6. Onshore sediments and volcanics, Hillsborough Basin.

The Oligocene section was treated as a whole; no attempt was made to sub-divide it into intervals (McKee et al., 1959, p.5).

Design of data base and coding forms

Despite the fact that the USGS workers in all of their studies summarized their data on standardized cards, it was decided for this study to experiment with a computerized data base. The categories of data to be included in the data base were taken from the 'basic' or 'station' edge-punched cards (Reynolds, 1964) formerly used by the Basin Study Group of the Petroleum Exploration Branch. C. Watt of the ADP Group designed the data base schema (Appendix 4) incorporating these categories, and two coding forms (Appendix 1 and 2), which are filled out as examples. The circled numbers on the coding forms refer to the explanatory notes (Appendix 3) written to assist compilers. ADP Group operators took the completed coding forms and entered the data into the Image data base management system on the Bureau's Hewlett Packard 2117F

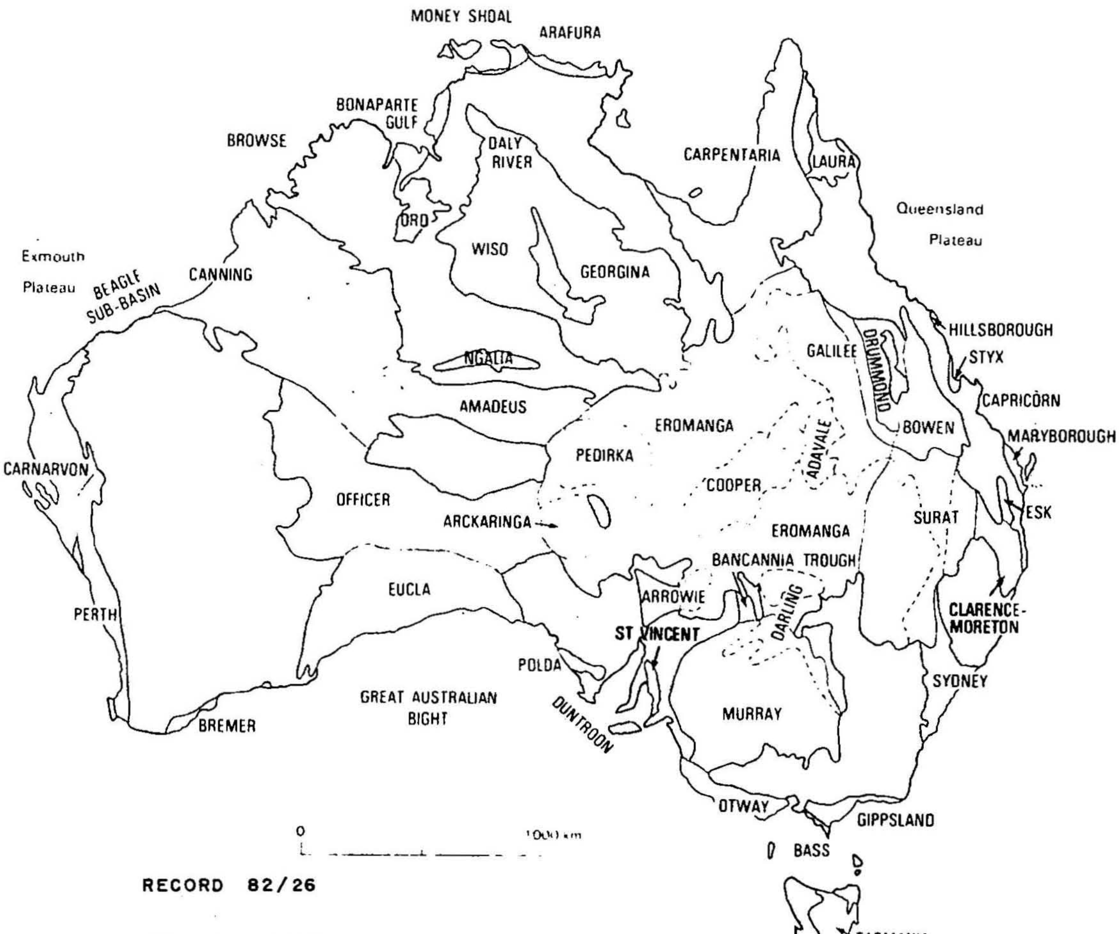

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Fig. 1 AUSTRALIA-SEDIMENTARY BASINS

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computer. After entering data from a number of coding forms the operator would supply the compiler with a printout of the data for checking. When this had been done, the compiler, by interrogating the data base, could obtain print-outs of relevant data for each observation point (petroleum exploration well) e.g. name of well, latitude and longitude, formation or epoch name, depth to top and base, details of lithology, fossils and so on.

Base maps:

Copies of map grids of the various basins, plus coastlines where present, with location of petroleum exploration wells plotted, were obtained on transparent paper at 1:500 000 scale by arrangement with the Marine Geophysics Group, using a computer program devised by F. Brassil which runs on CSIRONET (Brassil, 1982). Maps at 1:500 000 scale were used for the manual plotting of the Oligocene section top, base and thickness at each observation point. At the time, a program for plotting these parameters by each point was not available. These data were then hand-contoured, and the resulting compilations reduced by ratio machine to the final scale of 1:2 500 000.

PROBLEMS ENCOUNTERED

1. This project was not finished possibly because it was judged by management (perhaps because of its part-time nature) to be of less priority than other, continuing, projects.

2. The quality of data in well completion reports. This ranged from reasonable to poor. In very few instances were the data sufficient to provide information on events within the Oligocene; lithological and age data were scanty and vague. Some reports are incomplete because items have been 'lost' since the reports were received, but many reports lack important data when first lodged with BMR.

3. Manual versus computer-based storage of data.

a) There is, of course, a limitation to the amount of data that can be entered on the coding form - particularly in relation to descriptive material, such as that entered in the remarks field (max 3 x 72 characters). This was eventually overcome by noting in the remarks field that more information was written on the back of coding form 2 - quite a lot could be included in this way e.g. the section penetrated by the particular well, but of course this information could not be retrieved directly. The enquirer could only be informed that more information was available on the back of the form at Station-Number n, and he/she would have to go to the coding form to obtain it.

b) In some wells the Oligocene section consisted of several rock types for which the depths to top and base had been recorded; in order to put these data into the data base a separate coding form 2 had to be used for each rock type, with its top and base. When these data are retrieved using the IMFN program and printed out, the program records all the 'formation' tops together, and all the 'formation' bases together; this can be confusing, and it was found necessary to check the print-out against the coding forms to ensure that particular depths to tops were related to the correct depths to bases. It is understood that this problem of printing out of multiple entries can be overcome by using a different retrieval program IMDAD.

In this data base (PERST), the same need for multiple forms would arise if the complete section in a well were to be coded.

c) Under the storage system of well completion reports obtaining at the time of the study, there were practical difficulties in securing the loan of them promptly by BMR staff (in comparison with company personnel); usually BMR has only one copy of each report; several reports have been consulted so often that they are in poor condition, and some of them have important sections missing. Existing reports (apart from those previously published under the Petroleum Search Subsidy Acts) should be copied in batches on to microfiche so that at least what remains now in BMR is preserved. For new P(SL)A reports BMR should make it a condition that the company supplies microfiche copies as well as the usual paper copy.

The possession of a library of microfiche copies of well completion reports would make it much simpler for BMR personnel to borrow reports because multiple copies could readily be made, and those working on different parts of the geological column could each have copies. Furthermore people working on a particular basin could have the microfiche of all relevant well reports stored in their room for the duration of their project thus greatly reducing the time spent at present in obtaining well reports. This is not a direct problem of course to those with clerical or technical assistance, but too few members of staff are in that fortunate position.

Theoretically it would be of tremendous advantage to studies of this kind if all stratigraphic data from BMR well completion reports were stored in machine readable form. The practically insurmountable difficulty is the time and manpower required to perform this task, plus the possibility that perhaps much of the data coded may seldom or never be used. Most people who consult petroleum well completion reports are interested in only some of the data contained in them; this is certainly true of those engaged in studies of particular geological periods.

This suggests that a hybrid well information system is desirable, i.e. one that has in the computer, only some fairly basic data such as well location, company, title of report and where it can be consulted, basin name, reference to 1:250 000 map sheet, well elevation, total depth and ages of rocks penetrated, and perhaps a few keywords e.g. palaeontology, velocity summary, drill-stem test. It should not be an insuperable problem to enter this quantity of data for each well if the work were done systematically, beginning with the most recently drilled wells. The user could then, from the computer printout, list the wells of relevance to the problem, and consult the microfiche copies of the reports for the details he needs.

d) A problem with a computerised data base is the education of the potential users. The routines for interrogating the HP Image DBMS are simple but require a certain amount of practice before one becomes familiar with them; thus there are few problems for regular users. Unfortunately with a part-time project the time between sessions at the terminal may turn out to be months rather than weeks, and consequently the part-time user may have to re-learn how to use the system on each occasion. It is not unusual in such a time interval for there to have been minor improvements in the system which render the user's previous 'recipes' unworkable, and this is likely to create considerable frustration; this is because a simple request for a printout of wanted information, which regular users would handle in a few minutes, may take the occasional user half a day or longer, by the time he tries, fails and seeks help from an ADP specialist. (Of course the problem would not arise if a member of the project team were a technical officer familiar with data-base operations).

The writer adopted a method for overcoming the problem which in a way negates the whole idea of a computerised data base. This was to obtain two listings from the data base for each basin; one a list of station numbers in numerical order with the relevant well names, and the other a list of well names in alphabetical order with the relevant station numbers.

The number of the wanted well was then found from the alphabetical list, and the relevant coding form consulted for the needed data i.e. the coding form was used as the data card.

At the present (early 1982) stage of development of the BMR data base system and the ADP Group staffing, it is the writer's opinion that an edge-punch card system would be preferable to a computerised data base for any similar study in the near future because i) all the members of the project team can use it without difficulty; ii) staff members other than project team members can consult the data cards without having to learn how to access a computer data base; iii) there is virtually no limit to the amount or form of data that can be stored (by using additional cards for the same location, by sketch cross-sections, graphic logs); iv) the cards form a permanent data record; (they do not necessarily have to be punched at the outset but can simply be arranged alphabetically by well name; however, it would be desirable to be able to sort them by location at least).

RECOMMENDATIONS

It is recommended

1. that existing well completion reports held by BMR be copied on to microfiche in batches beginning with the recent reports, and working toward earlier ones;

2. that companies in future be required to provide BMR with microfiche copies of their reports in addition to the customary hard copies submitted at present;

3. that steps be taken to try to improve the quality of data that companies are required to lodge with BMR;

4. that period studies should be full-time projects; however if it is expedient that they be carried on as part-time activities it is recommended that they should use a card system data base, unless the project team includes a technical person who can devote considerable time to managing a computer data base.

PROGRESS

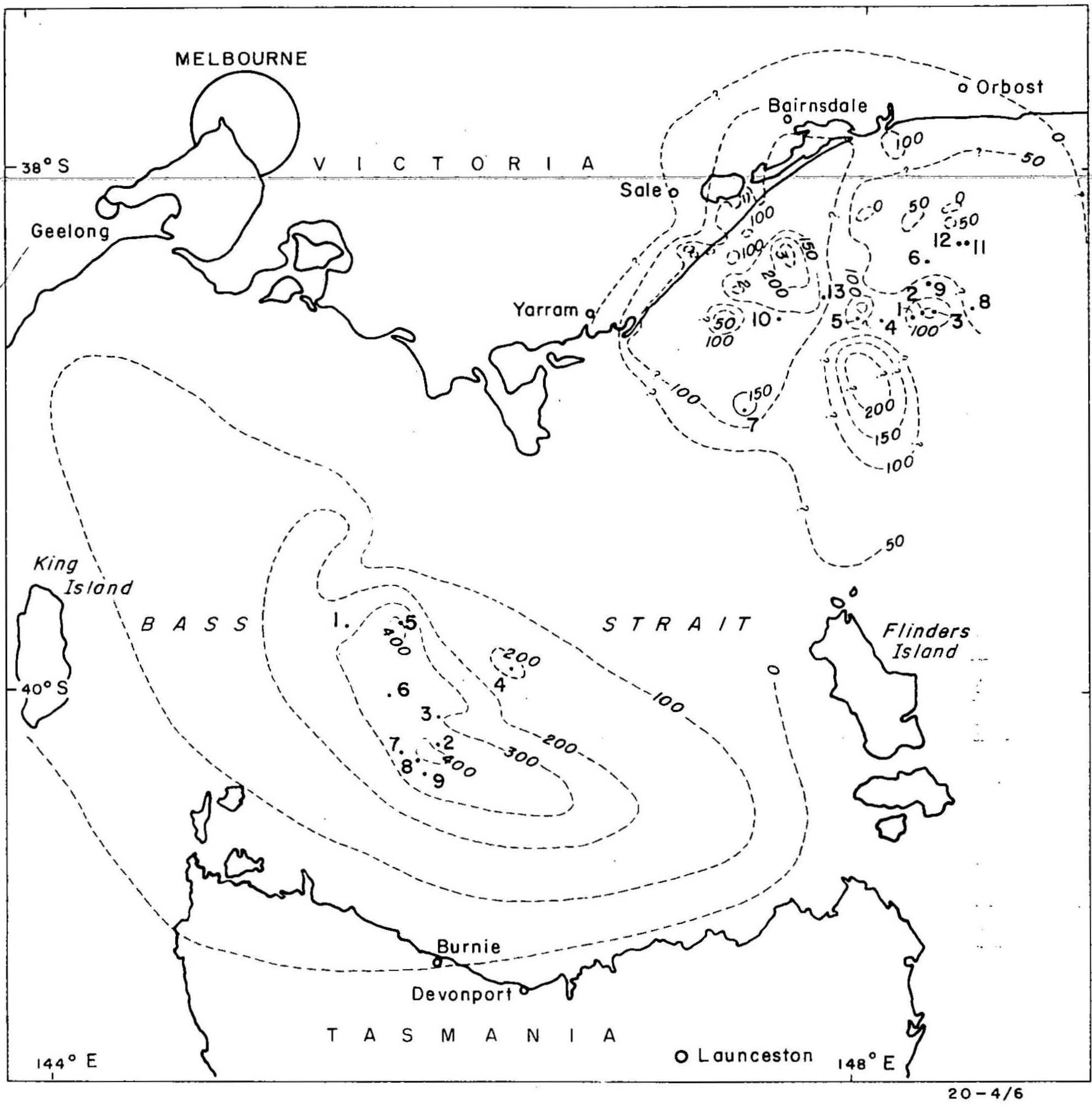
BASS BASIN

Information was obtained and coded from nineteen well completion reports, and for onshore Tasmania from Gill (1962). Rocks were assigned to the Oligocene on the basis of D.J. Taylor's work (Taylor, 1966, and unpublished micropalaeontological data sheets), supported by unpublished palynological data sheets by A.D. Partridge (1979). Table 1 shows the relationship of foraminiferal and palynological zonations to the geological time scale.

TABLE 1

m.y.	EPOCH		PLANKTONIC FORAMINIFERAL ZONATION Taylor (MS)	PALYNOLOGICAL ZONATION Stover, Partridge 1973	
			F		
	MIOCENE	Early	G	Upper	
22.5			H1		Proteacidites
			H2	Middle	
	OLIGOCENE	Late	I1		tuberculatus
32			I2	Lower	
		Early	J1		
37.5			J2	Upper	Nothofagidites asperus
	EOCENE	Late	K		

The contours on the top and base of the Oligocene interval (ignoring minor irregularities) have the shape of an elongate basin trending northward, and the isopachs (fig 2) form a discoid elongated northwest-southeast. The maximum thickness of Oligocene rocks is more than 450 m; they are predominantly fine-grained, and consist of marl, siltstone, calcareous in some wells, claystone, mudstone, shale, dolomite, sandstone, and in one well pyroclastic rocks interbedded with shale and silty sandstone.



0 100 200 km

BASS BASIN WELLS

1. Aroo-1
2. Pelican-3
3. Poonboon-1
4. Yurongi-1
5. Bass-1
6. Tarook-1
7. Narimba-1
8. Pelican-2
9. Pelican-1

GIPPSLAND BASIN WELLS

1. Kingfish-5
2. Bonita-1
3. Albacore-1
4. Kingfish-7
5. Gurnard-1
6. Fortescue-1
7. Groper-1
8. Hapuku-1
9. Cobia-2
10. Bullseye-1
11. Flounder-4
12. Flounder-5
13. Bream-2

Fig. 2 OLIGOCENE ISOPACHS

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The stratigraphic sequence in the northwest part of the Basin is as follows:

Late Eocene to Early Miocene	Torquay Group	(Puebla Formation (Jan Juc Formation
Late Eocene	Demons Bluff Formation	
Early Eocene	Boonah Formation	
Late Cretaceous to Paleocene	Eastern View Coal Measures	
Early Cretaceous	Otway Group	

The well reports for this area suggest there was uplift and regression near the end of the Eocene; the deepwater siltstone of the Demons Bluff Formation is followed by a sequence of shallow water, thinly interbedded sands, silts and marls that forms a transition to the deeper water, dominantly calcareous Torquay Group. The Oligocene Epoch is probably within the Jan Juc Formation. Elsewhere in several wells the Oligocene is represented in part by the Demons Bluff Formation and in part by the Torquay Group; this is indicated in the following stratigraphic table from the central part of the Basin:

Oligocene to Miocene	Torquay Group
Eocene to Oligocene	Demons Bluff Formation
Paleocene to Eocene	Eastern View Coal Measures

This is so in the north-central part of the Basin (Aroo-1 well, Figure 2) suggesting that the upper part of the Demons Bluff Formation is younger in the centre of the Basin than in the northwest; however in other wells further east and south (e.g. Pelican-3, Poonboon, Yurongi) the upper part of the Demons Bluff is regarded as Late Eocene, as in the northwest.

In the north-central part of the Basin the environment in the late Eocene is interpreted as tidal salt marsh; two short episodes of oceanic flooding brought in first, zonule K (late Eocene) planktonic foraminifera, and second (123 m higher) zonule J (early Oligocene) foraminifera; marine conditions persisted, but deposition was on a very shallow shelf until marine flooding (214 m higher than J) again brought in planktic foraminifera, this time of zonule I (late Oligocene). An attempt to relate these and similar events in other wells with Steele's (1976) transgression-regression chart for the Gippsland Basin, and with Vail et al's (1977) curve of relative sea-level change (Figure 3) was made, but it was realised that without more palaeontological data and close integration with seismic data, the correlations would have little reliability.

Forty km to the east of Aroo in Bass 1, shallow marine shale and sandstone deposition (zonules J2 to H2) in a restricted 'barred basin' environment is interrupted by a layer of pyroclastic rock during the time of zonule I. This is at about 29 m.y. In the Gippsland Basin Taylor (Cobia-2 Well Completion Report, Elliott, 1977) reports that Zonule I2 and part of I1 is missing.

Thirty km south of Bass 1 at Tarook 1 only zonules I1 and I2 are recognised, but these are in the upper 88 m of the total thickness of 352 m of Oligocene (as interpreted in the completion report), hence it is possible that the J zonules are present but unrecognised.

In the south of the basin, twenty-five km south-southeast of Tarook 1, in a group of wells comprising Narimba 1 and the three Pelican wells, no J2 zonule is recorded in any of the wells; Narimba 1 and Pelican 1 have J1 to H2, but no J at all has been reported in Pelican 2 and 3 despite a thick section of Oligocene.

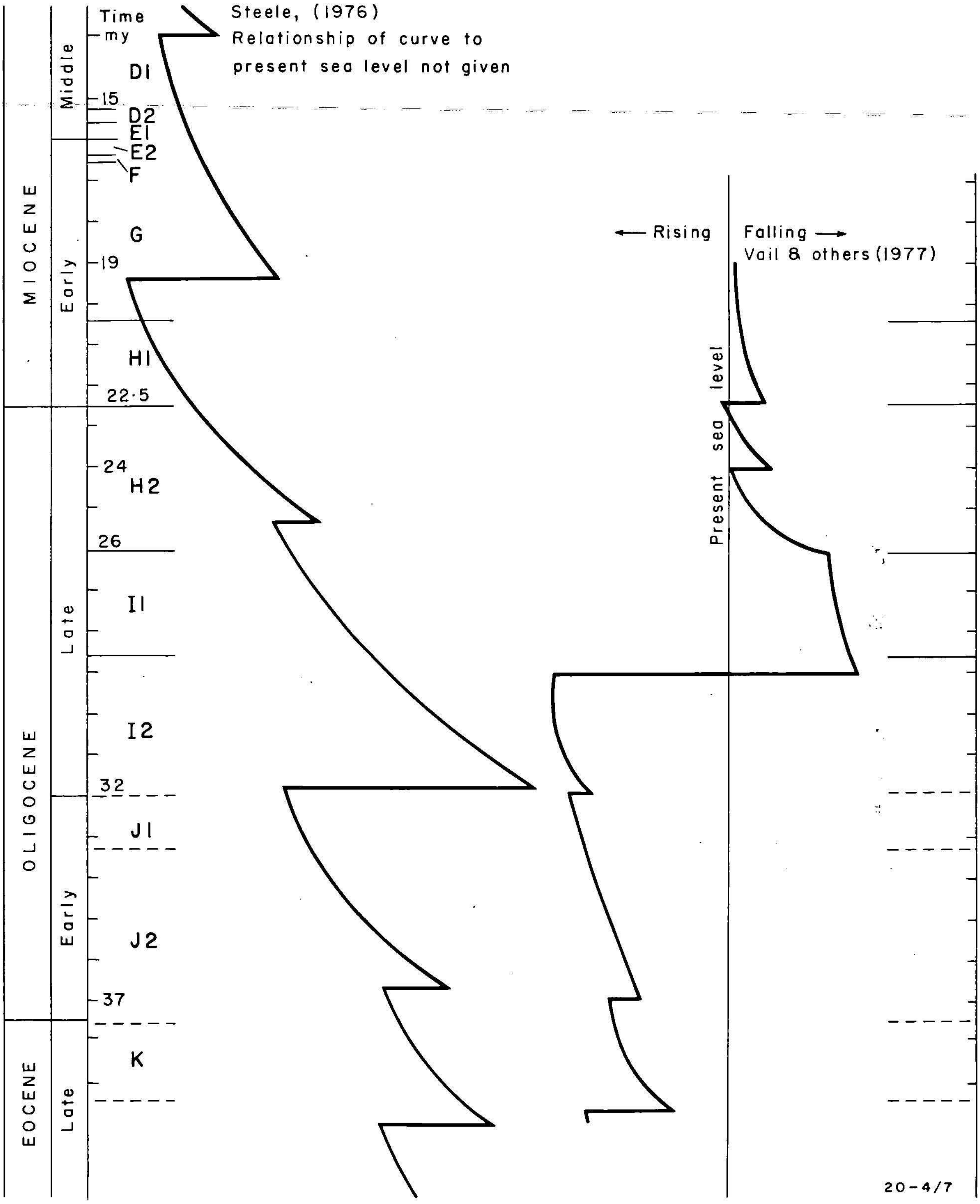

Fig. 3 Relative sea level curves in relation to planktonic foraminiferal zonations (Taylor in Partridge, 1979) and geological time scale

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GIPPSLAND BASIN

The well completion reports are remarkable for their incompleteness. Information from 100 reports was coded; of these 37 contained no information on palaeontology or on rock types penetrated; 7 reports had some information on palaeontology or palynology but nothing on rock type, and 15 reports contained information on rock types penetrated, but either lacked or had incomplete palaeontological/palynological information; that is, 59 reports out of 110 were incomplete.

Furthermore, in all wells, irrespective of whether reports are complete or not, it is clear that the resolution achievable through palaeontological zonation strongly depends on the quality and extent of the sidewall coring program, which in turn is based on information from rotary cuttings (Partridge, 1976, p.5).

Sufficient information however was available to enable an isopach map of the Oligocene interval at the scale of 1:½ million to be compiled; this was then reduced to a scale of 1:2.5 million (Figure 2). In places data points are very scattered, and the shapes of the contours could have been drawn with more confidence and accuracy had geophysical control been available.

Stratigraphically (Threlfall & others, 1976) the sequence most commonly penetrated is:

Miocene	Gippsland Formation = Gippsland Limestone
Oligocene	Lakes Entrance Formation
Palaeocene-Eocene	Latrobe Group = Latrobe Complex = Latrobe Data Complex = Latrobe Valley Coal Measures (onshore).

Details of the development of the nomenclature and of its variations are given by Robertson & others (1978).

The contact of the Lakes Entrance Formation with the Gippsland Formation is conformable, but the Lakes Entrance Formation rests unconformably on the Latrobe Group. This contact is difficult to recognise because commonly the lithology is sand on sand. The Lakes Entrance Formation is known only from subsurface studies.

Onshore the Lakes Entrance Formation is regarded as entirely of Oligocene age, and its thickness was used in constructing the isopach map; offshore however the age of the upper part of the formation ranges into early Miocene (in Kingfish-5 (Ford, 1974) the age ranges to zonule D2 - middle Miocene), hence in all wells having age control the Oligocene interval was used for the isopachs.

Lithologically, the Oligocene sediments are predominantly fine grained clastics - shale, siltstone, mudstone, claystone; in many wells calcareous and/or glauconitic, with marl, and with minor sandstone and/or limestone. The rocks are interpreted as having been deposited in an open marine environment during a transgression which began in the early Oligocene.

The thickest Oligocene section (450 m) was penetrated about 15 km northeast of Kingfish B Oil Field (Figure 2) in Bonita-7 and Albacore-1 wells, but unfortunately no information on palaeontological control or lithology was available.

The earliest Oligocene rocks - zonule J2 - are reported in the vicinity of the Kingfish Oil Fields (Kingfish-7, Gurnard-1), 100 km to the north (Fortescue-1), nearly 400 km to the southwest (Groper-1), and possible J2 150 km to the east (Hapuku-1); hence the transgression took place early in Oligocene time and was widespread.

However information from this central part of the basin indicates that typically the Oligocene epoch is incompletely represented; zonule I2 is missing, and this is reported as being the case in most deepwater Gippsland sequences (Kemp, 1975). In Kingfish-7 (Elliott, 1977) and Cobia-2 (Taylor in Elliott, 1977) zonule I2 and part of I1 are missing, and in the latter well the foraminifera samples above and below the missing interval are deep water forms. Taylor writes that the biostratigraphic span of the hiatus (the 'Cobia Event') is consistent in other wells (though there is a larger break in the nearby Fortescue-1 well (zonules J1, I2 and I1), (Taylor in DoRosario & Thornton, 1978).

Zonule H2 at the top of the Oligocene is reported only in Fortescue-1, Kingfish-5 and Bullseye-1 wells, but it is probably widely represented, as in most wells the Oligocene is overlain conformably by rocks of Miocene age. Exceptions noted are Hapuku-1 where only zonule J2 or K is recorded, and a thin section is attributed to non-deposition; Flounder-4 where only zonule J1 is recorded, and Oligocene greensand is overlain unconformably by Gippsland Formation; and Flounder-5 where only zonule I1 is recorded, and Oligocene shale is overlain disconformably by Miocene.

Faulting of the Bream anticline, probably in the late Oligocene, is reported by Esso (Bream-2, 1979).

Figure 3 shows Steele's (1976, Fig. 9) relative sea level curve for the Gippsland Basin related to Partridge's (1979) table of planktonic foraminiferal zonations and the relative sea level curve of Vail and others (1977). According to Steele's curve, a sharp relative fall of sea level takes place at about the top of zonule J1 (32 my), the boundary between Early and Late Oligocene, followed by a gradual relative rise through the time of I2 and I1, then a minor relative fall in early H2 time. The absence of I2 and part of I1 zonules from the Cobia-2 section is consistent with Steele's curve, though the recording of deep water forams immediately above the break requires explanation.

Taylor (in Elliott, 1977) writes that "the 'Cobia Event' falls within the biostratigraphic time span of three events of regional and world-wide significance: 1. a deep sea unconformity in the Tasman and Coral Seas, attributed by Kennett et al (1975) to a major reorganisation of the oceanographic systems in the Southern Ocean; 2. a world-wide palaeo-temperature decline; 3. a profound eustatic event of low sea level, corresponding with the top of zonule J1."

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Appendix 1

PERIOD STUDY DATA BASE CODING FORM 1

Station (1)	STNN1	80JP0137
	AUTHR	Esso Exploration Australia, Inc.
	AUTHR	
Authors (2)	AUTHR	
	AUTHR	
	AUTHR	
	AUTHR	
	AUTHR	
	AUTHR	
	TITLA	Esso Bass-1 Tasmania Well Completion Report
Title of	TITLB	
Article (3)	TITLC	
Journal name (4)	DOCTP	
Vol/Pt/page	VOLNO	BMR File 65/4167
Publ. Year	PYEAR	1965
Well name	WELL	Bass-1
State (5)	STATE	Tas
	BASNP	Bass
Basin or	BASNP	
Province	BASNP	
name	BASNP	
250k map no.	MAPNO	SJ/55-14
100k map no.	HUNNO	
Detail locn.	DETLC	
Latitude	LATD	39,46,18 S
Longitude	LONG	145,44,03 E
Grid northing	KMGDN	
Grid easting	KMGDE	
Elevation feet (6)	ELEVF	0 — Elevation metres ELEVM 0 (RT = 31' but depths are referenced to sea level)
Subjects	SUBJ	palaeontology
	SUBJ	
covered (7)	SUBJ	
	SUBJ	
	SUBJ	
	SUBJ	
CONFIDENTIAL?		No

PERIOD STUDIES DATA BASE CODING FORM 2

	Station (1)	STNN5	80JP0137			
	Unit name (8)	UNAME	Oligocene			
	Unit type	UTYPE	EPOCH			
	Depth to top feet	TOPF	-3819	Depth to top metres	TOPM	-1164
	Depth base ft	BASEF	-5169	Depth base m	BASEM	-1576
	Thickness ft	THKNF	1350	Thickness m	THKNM	412
	Method (9)	METHD	sample log			
TOP CONTACT	Ut. name (10)	TPCON	Miocene			
TOP CONTACT	Ut. type	TPTYP	EPOCH			
TOP CONTACT	Cnt. type	TCONT	conformable			
TOP CONTACT	Epoch	TEPCH	Oligocene			
TOP CONTACT	Ea/Md/Lt	TSBEP	Late			
TOP CONTACT	Age	TAGE				
TOP CONTACT	Dated by (11)	TDTE	forams			
TOP CONTACT	Zone name	TZONE	H2			
TOP CONTACT						
TOP CONTACT	Zone author	TZNAU	Taylor, D.			
TOP CONTACT	Datum	TDATM				
TOP CONTACT	Mill.yrs.	TMYRS				
BOTTOM CONTACT	Ut.name (12)	BPCON	Eocene			
BOTTOM CONTACT	Ut.type	BPTYP	EPOCH			
BOTTOM CONTACT	Cnt.type	BCONT	conformable			
BOTTOM CONTACT	Epoch	BEPCH	Oligocene			
BOTTOM CONTACT	Ea/Md/Lt	BSBEP	Early			
BOTTOM CONTACT	Age	BAGE				
BOTTOM CONTACT	Dated by	BDTE	forams			
BOTTOM CONTACT	Zone name	BZONE	J2			
BOTTOM CONTACT						
BOTTOM CONTACT	Zone author	BZNAU	Taylor, D.			
BOTTOM CONTACT	Datum	BDATM				
BOTTOM CONTACT	Mill.yrs.	BMYRS				
		RKTYP	shale, fossiliferous			
	Rock type (13)	RKTYP	sandstone, dolomitic & calcareous			
		RKTYP	mudstone, calcareous			
		RKTYP	siltstone, calcareous			
		RKTYP	tuff			
		RKTYP				
	SS/Shale %	SSPCT				
	LM/anhyd. %	LMPCT				
	Sample type (14)	SAMPL	cores, cuttings			
	Palaeogeog. (15)	PALAE	marine			
	Associated	MINRL				
	Mineral	MINRL				
	deposits	MINRL				
		REMK1	Oligocene contains 235ft pyroclastic ref			
	Remarks		erred to as tuffite. Oligocene is			
		REMK2	overlain by sandstone, rests on siltstone			
			. Depths from Partridge, 1979.			
		REMK3				

Notes on Period Study Data Base Coding Forms 1 and 2

General: follow the style in the example forms

1. Station number refers to a geographic location: it is made up of the last two digits of the year of compilation, two initials of the compiler's name, followed by a four figure sequencing number. Use the same station number on form 1 and 2.

2. Author(s): if the article has more than four authors, fill in the additional names on another form 1 using the same station number. Use upper and lower case letters. Periods after initials are important.

3. Title: enter the title first in the field TITLA, then TITLB, then TITLC. Abbreviate if necessary. Use upper and lower case letters. Start the TITLB and TITLC fields at the beginning of a new word.

4. Journal name: For preference write journal name in full, but abbreviate if longer than 72 characters. Use upper and lower case letters.

5. State or Territory: use the following abbreviations: Qld, NSW, Vic, Tas, SA, WA, NT, ACT.

6. Elevation: enter elevation in either feet or metres in the appropriate spaces; right justify numerals. Elevations of oil exploration wells and depths to formation tops therein are usually referenced to KB (kelly bushing). Ensure that the figures used in forms 1 and 2 are referred to the same datum. Give depths below sea level a negative sign.

7. Use key words: lithological analysis, sedimentary structures, palaeontology, provenance, palaeogeography, palaeotectonics, palaeogeology, isopach map, facies map, fence diagram, cross section, regional correlation, clay mineralogy, geochemistry.

8. Unit can be a rock unit i.e. formation, group, beds or interval, or a division of time e.g. epoch. Whichever is meant is entered at Unit Type in capital letters.

9. Method refers to the way in which thickness was determined: use key words: measured, electric log, sample log, map, estimate, composite.

10. Unit name, top contact: this refers to the name of the overlying unit. The age (i.e. epoch etc) is that of the subject unit at its contact with the overlying unit.

11. Dated by: fossils, bracket, estimate, lithology, palaeomagnetism.

12. Unit name, bottom contact: this refers to the name of the underlying unit. The age is that of the subject unit at its contact with the underlying unit.

13. Rock type: use simple terms e.g. sandstone, shale, limestone, dolomite etc.

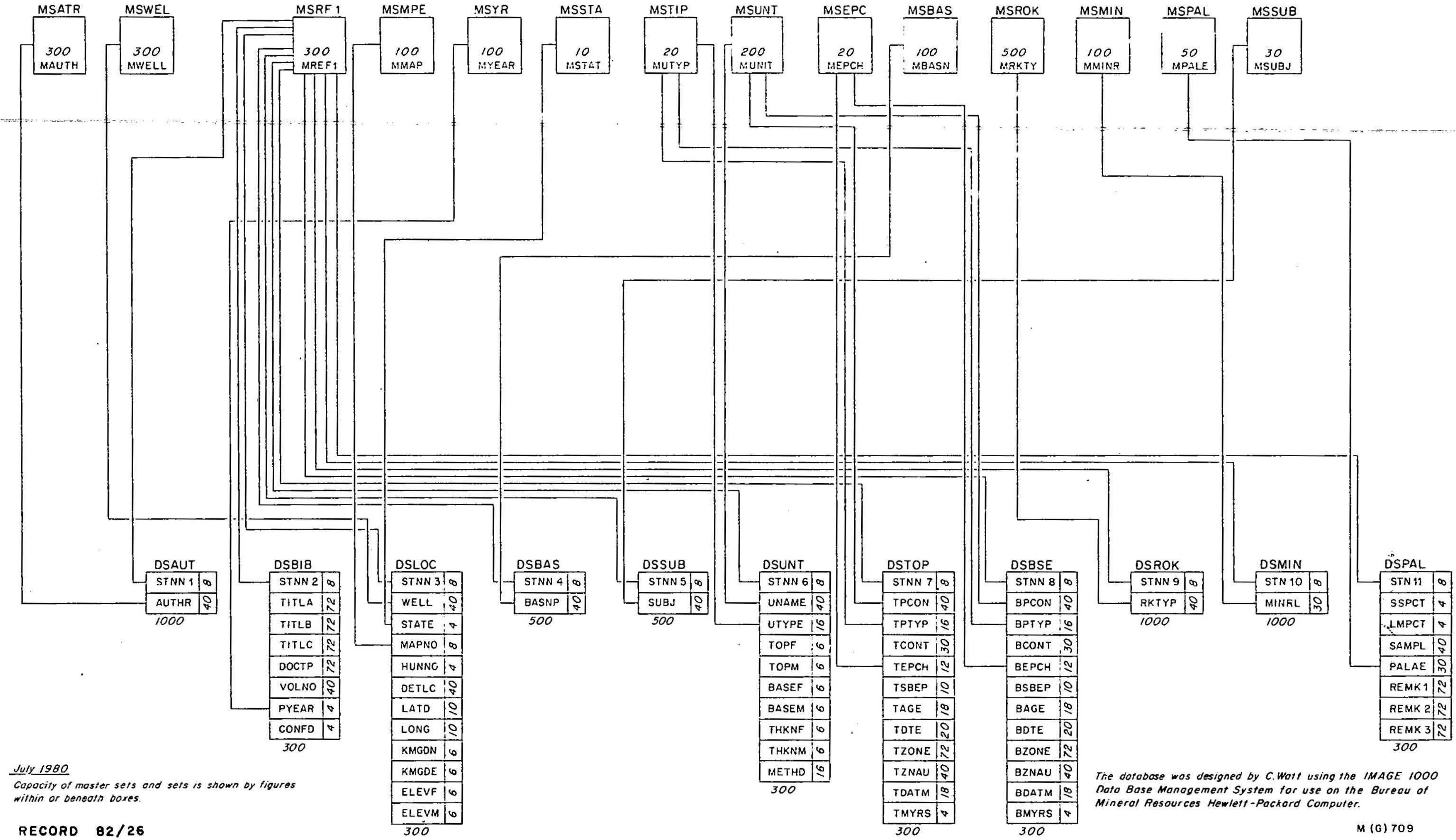
14. Sample type: outcrop, core, sidewall core, cuttings.

15. Palaeogeog i.e. environment of deposition (author's interpretation) e.g.:

Continental	- dune; flood plain; alluvial fan; playa; lake; glacial; swamp; volcanic.
Marginal	- delta; beach; lagoon, evap.; lagoon, humid.
Marine	- near-shore; normal sea; uncircul. sea; biostrome; volcanic

PERST DATA BASE STRUCTURE

Appendix 4



July 1980

Capacity of master sets and sets is shown by figures within or beneath boxes.

The database was designed by C. Watt using the IMAGE 1000 Data Base Management System for use on the Bureau of Mineral Resources Hewlett-Packard Computer.

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M (G) 709

Appendix 5

LIST OF WELL REPORTS CONSULTED

BASS BASIN

Well	Station number
AROO-1	80JP0136
BASS-1	80JP0137
BASS-2	80JP0138
BASS-3	80JP0131
CORMORANT-1	80JP0141
DONDU-1	80JP0143
DURROON-1	80JP0146
KONKON-1	80JP0144
NANGKERO-1	80JP0135
NARIMBA-1	80JP0132
NERITA-1	80JP0134
PELICAN-1	80JP0147
PELICAN-2	80JP0148
PELICAN-3	80JP0149
POONBOON-1	80JP0139
SNAIL-1	80JP0133
TAROOK-1	80JP0142
TOOLKA-1A	80JP0140
YURONGI-1	80JP0145

GIPPSLAND BASIN WELLS

Well	Station number
Albacore-1	79JP0010
Albatross-1	79JP0009
Bairnsdale-4	79JP0095
Barracouta-3	79JP0007
Batfish-1	79JP0008
Bellbird-1	79JP0084
Bluebone-1	79JP0016
Bonita-1a	79JP0014
Bream-2	79JP0012
Bream-3	79JP0013
Bullseye-1	80JP0109
Bumberrah-3	79JP0090
Carrs Creek-1	79JP0004
Cobia-1	79JP0054
Cobia-2	79JP0098
Cod-1	80JP0103
Colliers Hill-1	79JP0082
Crossroads-1	79JP0076
Darriman-3	79JP0089
Dart-1	79JP0015
Dolphin-1	79JP0083
Duck Bay-1	79JP0005
Dutson Downs-1	79JP0068
East Reeve-1	79JP0077
Emperor-1	80JP0101
Esso Gippsland Shelf-1 (Barracouta-1)	79JP0019
Flathead-1	79JP0029
Flounder-1	80JP0104
Flounder-2	79JP0020
Flounder-3	79JP0021
Flounder-4	79JP0022
Flounder-5	79JP0023
Flounder-6	79JP0024
Flying Fish-1	79JP0053
Fortescue-2	79JP0062
Fortescue-1	79JP0061

GIPPSLAND BASIN WELLS

Well	Station number
Fortescue-3	79JP0063
Fortescue-4	79JP0064
Gannet-1	79JP0011
Golden Beach West-1	79JP0069
Golden Beach-1A	79JP0070
Groper-1	79JP0030
Groper-2	79JP0031
Gurnard-1	79JP0058
Halibut-1	79JP0057
Hapuku-1	79JP0037
Hedley-1	80JP0102
Keystone-1	79JP0078
Kingfish-5	79JP0032
Kingfish-6	79JP0033
Kingfish-7	79JP0036
Lake Reeve-1	79JP0067
Mackerel-1	79JP0027
Mackerel-2	79JP0025
Mackerel-3	79JP0026
Mackerel-4	79JP0028
Marlin-1 (Gippsland Shelf-4)	79JP0038
Marlin-4	79JP0039
Marlin-A24	80JP0108
Marlin-A6	80JP0107
Meerlieu-1	79JP0092
Merriman-1	79JP0003
Milton-1	79JP0017
Moray-1	79JP0034
Morwong-1	79JP0040
Mullet-1	79JP0056
Nannygai-1	79JP0035
Nindoo-1	79JP0093
North Seaspray-1	79JP0002
North Seaspray-2	79JP0066
Nuntin-1	79JP0094

GIPPSLAND BASIN WELLS

Well	Station number
Pelican Point-1	79JP0096
Perch-1	79JP0055
Pike-1	79JP0048
Rockling-1	79JP0060
Rosedale-1	79JP0018
Sailfish-1	79JP0051
Salmon-1	79JP0044
Salt Lake-1	79JP0071
Seacombe South-1	79JP0073
Seaspray-1	79JP0001
Snapper-2	79JP0050
Snapper-3	79JP0049
Sole-1	80JP0099
South Longford-1	79JP0085
Southwest Bairnsdale-1	79JP0006
Spoon Bay-1	79JP0072
St. Margaret Island-1	79JP0086
Stonefish-1	79JP0045
Sunday Island-1	79JP0088
Sunfish-1	79JP0046
Swordfish-1	80JP0110
Tailor-1	79JP0043
Texland-1	79JP0091
Trevally-1	79JP0042
Tuna-1	80JP0100
Tuna-2	79JP0041
Tuna-3	80JP0105
Turrum-1	80JP0106
Turrum-2	79JP0052
Wahoo-1	79JP0047
Wellington Park-1	79JP0074
Wellington Park-2	79JP0075
West Halibut-1	79JP0059
West Seacombe-1	79JP0079
Woodside Lakes Entrance-1	79JP0065

GIPPSLAND BASIN WELLS

Well	Station number
Woodside South-1	79JP0087
Woodside-1	79JP0080
Woodside-2	79JP0081
Woodside-4	79JP0097