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GEORGINA BASIN PROJECT PROGRESS REPORT 1974-79

by

J.H. Shergold
(Project Coordinator)

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ABSTRACT

Advances in knowledge arising from activities of, and associated with, the BMR multidisciplinary study of the Georgina Basin during the period 1974-79 include: a refinement of the biostratigraphic time scale, a greater understanding of the structural evolution of the basin, the recognition of recurring evaporite environments during deposition of some units, the identification of oil shale, hydrocarbon traces and source rocks, and new information on the thermal history of the basin. A total of 94 papers and maps, published, in press, or in preparation at 31 December 1979 are listed as are personnel involved with the Project.

Contents

1. INTRODUCTION

The Georgina Basin Project was started in 1974 as a pilot study for multidisciplinary projects in BMR (Druce, 1974). It was primarily conceived as a stratigraphical (sedimentological/palaeontological) analysis of the eastern and southern margins of the basin, and it was considered that the results would contribute to the search for hydrocarbon accumulations and base metal deposits. Lithological, sedimentological, biostratigraphical, petrological, and inorganic geochemical studies were started, to produce a synthesis of the geological development of the basin.

Phase 1 of Georgina Basin activities essentially involved a field-orientated geological and geophysical stocktake of the basin. An annotated bibliography (Druce & Shergold, 1978) listing all known references to December 1976, and reviews of the geology (Shergold & Druce, in press) biostratigraphy (Shergold, 1975b), shallow crustal geophysics (Tucker & others, 1979), base-metal mineralisation (Draper, 1978c), and petroleum prospects (Draper & others, 1978), have been compiled. Officers of the Geological Survey of Queensland (GSQ) have prepared reviews of mineral exploration in the following 1:250 000 Sheet areas which cover parts of the Georgina Basin; Duchess (Noon, 1976), Lawn Hill (Hutton, 1977), Mount Isa (Wilson, 1977) Urandangi (Noon, 1977), Camooweal (Wilson, 1978), Glenormiston (Green, 1978), Boulia (Green, 1979).

A major seismic survey was undertaken in the Toko Syncline during 1977 (Mathur & Bauer, 1977; Harrison, 1976, 1979, in prep.; Harrison & Schmidt, 1978). Additionally, twenty-six stratigraphic holes have been drilled in the Georgina Basin, twenty-four by BMR (Kennard & Draper, 1977; Shergold & Walter, 1979), and two by GSQ (Green & Balfe, in prep.).

Two 1:100 000 scale Geological Sheets have been published, Southern Burke River Structural Belt (BMR, 1976) and Adam Special (BMR, 1978). Toko and Abudda Lakes Sheets are in preparation by BMR, and Mount Whelan by GSQ.

Various specialist investigations have been initiated; some have been completed, but others, according to their time-consuming nature, continue. To disseminate summary results of these investigations an informal newsletter, Georgina Research, is produced quarterly and distributed on the Open File system. To date four newsletters, commencing December Quarter 1978, have been issued (Shergold 1979,a,b,c,d). All information produced has been placed on an INFOL data storage and retrieval system run on a Cyber 76 computer (Smith, 1978)

Since its inception, 42 scientists from 20 organisations have been involved in the Georgina Basin Project. Of these, 23 have been BMR officers from Geological, Geophysical, Petroleum Exploration, and Operations Branches, and 19 from other organisations, such as CSIRO, Museums, Universities, State Government, and other Commonwealth Departments. Three overseas specialists have been involved in the Project (see attached list of personnel and organisations). Nineteen BMR staff, three from GSQ, three from CSIRO, and nine from other organisations continue to work on material generated by the Georgina Basin Project.

With such a large number of personnel involved, a form of Project Management has been initiated in BMR to coordinate the various activities of the Project. A Project Coordinator supervises individual tasks, coordinates activities in both field and laboratory, and is responsible for seeing that the results are produced in reasonable time. The Coordinator is responsible directly to a Project Manager who supervises three distinct BMR projects.

2. SUMMARY OF ACTIVITIES 1974-79

Activities are listed here by discipline for convenience: interests of personnel have often overlapped discipline boundaries and resulted in unique multidisciplinary approaches to problem solving.

2.1 Sedimentology

The Project staff have made detailed analyses of the sedimentology and depositional environments of Upper Cambrian, Lower and Middle Ordovician, and Devonian lithological units; these units were poorly understood prior to the present Georgina Basin Project. Upper Cambrian and Lower Ordovician carbonate units have been examined with respect to their potential trapping of base metals and petroleum. The Arrinthrunga Formation in the west and Chatsworth Limestone in the east of the basin have been studies by Kennard (in prep.), the Georgina Limestone by Green (in prep.), and the Ninmaroo Formation by Radke (in prep. a,b,c,d,e; Radke & Mathis, in prep.). Lower and Middle Ordovician clastic sediments, Carlo Sandstone, Mithaka Formation, Ethabuka Beds, as well as the Devonian Cravens Peak Beds and 'Thelodont-bearing' beds, have been investigated by Draper (1976a, 1977, in prep. a, b, in Turner et al., in prep.). The Lower Ordovician Kelly Creek, Coolibah, and Nora Formations have been studied by Druce (in prep. a, b, c). Middle Cambrian units have not been studied as widely: West has examined the Marqua Beds and Arthur Creek Beds of the southern and

southwestern portions of the basin, while Southgate (in prep.) is studying the relationship between carbonate depositional mosaics, evaporites, and phosphorites along the northeastern margin, between Lawn Hill and Ardmore. Sedimentological studies on Lower Cambrian stratigraphic units between Hay River and Huckitta are planned.

2.2 Palaeontology

Considerable attention has been paid to fossil groups which are considered important in providing high-degree resolution biochronology in the basin.

Druce has extended his earlier conodont work into the Middle Ordovician, and has described the conodont faunal assemblages of the Kelly Creek, Coolibah, and Nora Formations, Carlo Sandstone, and Mithaka Formation (in prep. a, b, c). Shergold has described late Cambrian and initial Ordovician trilobite assemblages, concentrating on the pelagic agnostid elements, and has formulated an informal biostratigraphy in the carbonate sequences of the Burke River Structural Belt (Shergold, 1975 a. 1977, in press a, b). The Ordovician trilobites of the basin are currently being investigated by Shergold and Fortey. Inarticulate brachiopods, also biochronologically important, are being investigated by Henderson (see Rowell & Henderson, 1978).

Cambrian and Ordovician molluscs are being studied. Late Cambrian and Early Ordovician rostroconch molluscs have been described by Pojeta et al. (1977), materially complementing knowledge of faunal associations in the Cambrian-Ordovician transition interval. Ordovician pelecypod molluscs have also been described by Pojeta & Gilbert-Tomlinson (1977). Contemporaneous cephalopods are being described by Wade (1977 a, b), again contributing greatly to the biochronology of this interval. Early and Middle Cambrian molluscs are under study by Runnegar.

Studies of phosphatised Middle Cambrian faunal assemblages have been started by McKenzie and Jones who have described bradoriid ostracodes (McKenzie & Jones, 1979 and Jones & McKenzie, in prep.). Other elements of these faunas will be described by McKenzie, Runnegar, and Shergold.

Kruse and West (in prep.) have described Early Cambrian archaeocyathids from the Hay River and Huckitta region and have related them to faunas from the Amadeus Basin and Flinders Ranges. Walter, Krylov, & Preiss (1979) have studied Proterozoic stromatolites from the southwest of the Georgina Basin, and similarly related them to floras from the same two areas. Acritarchs have been identified from the earliest Cambrian in the Hay River area by Muir (1979).

Devonian fish faunas from the Dulcie and Toko-Toomba Ranges are being described by Young. Descriptions of thelodont scales from the Toko Ranges have been prepared for publication Turner, Jones & Draper, in prep.).

Conodont colouration has been used by Druce to determine post-depositional heating of Toko Group sediments in Alliance Ethabuka No. 1, and Nicoll has applied similar techniques to the Ninmaroo Formation.

2.3 Geochemistry

Various geochemical studies have been undertaken during the course of Phase 1 activities in the Georgina Basin. Draper (1976b, 1978a,b) has analysed surface and subsurface samples of Pomegranate Limestone, Chatsworth Limestone, Ninmaroo Formation, and Swift Formation in the Burke River Structural Belt, and of the Arrinthrunga Formation, Georgina Limestone, Ninmaroo Formation, Kelly Creek Formation, Coolibah Formation, and Nora Formation in the Toko Syncline and the Huckitta area. Two groups of analyses were made: 1) HCl-soluble Ca, Mg, Sr, Fe, Mn, and acid-insoluble residues; and 2) HF-soluble or whole-rock Cu, Pb, Zn, Ba, V, F, and organic carbon.

Inorganic analyses have been made by AMDEL and BMR laboratories on surface samples in the Desert Syncline (Hay River 1:250 000 Sheet),and on subsurface samples from BMR Hay River Coreholes 10, 11, 11A and 11B (Shergold & Walter, 1979, tables 2-6). AMDEL has also conducted analyses on material from GSQ Mount Whelan Coreholes 1 and 2 (results in Green & Balfe, in prep.). A more detailed appraisal of the geochemical profile in the Hay River coreholes is in progress.

A detailed organic geochemical analysis of BMR Hay River and GSQ Mount Whelan corehole material is being undertaken by K. Jackson (in prep.). Analyses include total organic carbon (TOC), total extractable organic matter (EOM), gas chromatography on saturated hydrocarbons in the EOM, vitrinite reflectance; and infra-red, X-ray diffraction, and elemental analyses are applied to selected kerogen isolates. These analyses give some idea of the type of organic material present, its state (oil/gas), volume, and the degree of heating to which it has been subjected. Some results for Hay River material are published in Shergold & Walter (1979, table 7). Mount Whelan analyses are included in Green & Balfe (in prep.).

Pyrobitumen from the Red Heart Dolomite in BMR Hay River No. 11A, has been analysed by CSIRO and identified as mesophase (a precursor to coke) (Russell,MRL). Quartz crystals in this formation contain fluid inclusions which

are under investigation by Wilkins (MRL). These inclusions contain hydrocarbon gas in an immiscibile relationship with an aqueous solution. Temperature studies on both the mesophase and fluid inclusions continue.

Black shale intervals in BMR Mount Isa No. 1 are under investigation as possible oil shales by Gibson who has initiated organic geochemical analyses on samples from this well.

The relationship of organic carbon to phosphorus is being investigated as a Ph.D. study by Sandstrom. Fresh phosphorite for this purpose has been obtained from BMR Duchess Nos. 14 and 14A (see Sandstrom in Shergold & Walter, 1979, table 1).

2.4 Geophysics

Geophysical activities during Phase 1 of the Georgina Basin Project have mainly comprised: (1) a major seismic survey in the Toomba Range; (2) a review of the crustal geophysics of the whole basin along selected traverse lines; (3) a detailed airborne magnetic and radiometric survey of a portion of the Glenormiston area; and (4) palaeomagnetic and thermal conductivity studies.

The Toomba Range seismic survey was designed to obtain a seismic stratigraphical profile between PAP Netting Fence No. 1 in the north and FPC The Brothers No. 1 in the south. This section passes through Alliance Ethabuka No. 1 and ties together earlier seismic traverse lines run by BMR and Exploration Companies, mainly in the early sixties. Stratigraphic coreholes drilled by GSQ (Mount Whelan Nos. 1 and 2) were also tied to this section, and lateral traverses were conducted across the Toomba Fault (see Mathur & Bauer, 1977; Harrison, 1976, 1979, in prep,; Harrison & Schmidt, 1978). These activities have substantially implemented geological knowledge on the distribution of formations, and provided a structural analysis of the Toomba Fault Zone and adjacent rocks.

Harrison and Mathur have also been involved with a review of the Pre-Cambrian basement crust beneath the Georgina Basin (Tucker et al., 1979). In this study Tucker and Wyatt examined the gross magnetic and gravity features of the basin and on the basis of pattern recognition of regional Bouguer anomalies and total-magnetic-intensity contours were able to subdivide the basin into areas that have internally consistent geophysical patterns. An extrapolation of the geology of these areas was made by Druce; traverses crossing major features were selected to incorporate subsurface geological and seismic information (Druce, Harrison, Mathur); detailed geophysical and geological modelling along

these lines was undertaken by Tucker, Wyatt and Druce; and a final synthesis of the regional crustal geology prepared (Wyatt & Tucker, 1979).

A detailed airborne magnetic and radiometric survey, flown in 1977 in the Glenormiston 1:250 000 Sheet area, was designed to investigate the southern extension of the Mount Isa Block and, if possible, its relationship to the Arunta Block (J. Rees). Seventy one flight lines and thirteen ties were flown. The data have been prepared and are being interpreted.

Specimens from Upper Proterozoic tillitic sequences have been demagnetised to determine the general magnetic characteristics of the material and what treatments are required to obtain meaningful results (M. Idnurm). A distinct grouping of measurements around a shallow westerly inclination is indicated, and this is consistent with measurements from the Amadeus Basin and Adelaide Geosyncline, reinforcing the paradoxical association of tillites with low palaeolatitudes.. Magnetostratigraphic measurements across the Precambrian-Cambrian boundary have helped to correlate the Adelaidean and Early Cambrian sequences of the Georgina Basin with those elsewhere (see Burek et al., 1979).

J.P. Cull has begun heat-flow studies of core samples from GSQ Mount Whelan No. 1 as a contribution to the creation of thermo-tectonic models of basin formation. To date thermal conductivities of thirteen cores from this hole have been measured, nine of which were basement samples. Preliminary results have been achieved.

2.5 Maps

Early in the project the field information collected in the Burke River Structural Belt was recorded on 1:100 000-scale maps, principally to present data resulting from the detailed sedimentological and palaeontological studies of the Chatsworth Limestone, Ninmaroo Formation, and Swift Formation. A 1:100 000-scale map of geology of the Southern Burke River Structural Belt was published in 1976 (BMR). Subsequently, detailed field observations were undertaken near the southern margin of the Georgina Basin. Investigations of the late Proterozoic sequence and related activities in the Hay River 1:250 000 sheet and neighbouring areas, gave rise to the 1:00 000-scale Adam Special preliminary geological map (BMR, 1978). Field data were collected over several 1:100 000 Sheet areas and compilation of three additional preliminary geological maps is in progress. Toko and Abudda Lakes (BMR, in prep.), and Mount Whelan (GSQ, in prep.), are scheduled to be published early in 1980.

It is envisaged that the new information on the Proterozoic and Cambrian geology in the Hay River and Tobermory 1:250 000 sheet areas will be produced as a special revised 1:250 000 sheet by amalgamation of the relevant parts of the 1:100 000 sheets.

3. SUMMARY OF MAIN ACHIEVEMENTS

3.1 Subdivision of the Proterozoic lithostratigraphic sequence along the southern margin of the Georgina Basin into six formations has facilitated a detailed analysis of the distribution of Late Proterozoic depositional environments and interpretation of structural control over sedimentation. A review of crustal geology underlying the Georgina Basin has indicated eight infra-basins, each containing over 1000 m of Adelaidean strata. An estimated 10 000 m occurs in the Toko Syncline area. A high, variable hinterland relief, and horst and graben structures, the latter containing up to 5000 m deposited locally, are predicted. Among late Proterozoic lithofacies, black shales overlying tillitic sequences are potential petroleum source rocks, and dolomite units potential base metal host rocks.

3.2 At all localities in the Georgina Basin which have been investigated in detail, Cambrian rocks lie unconformably on late Proterozoic or older sequences. This fact has implications for petroleum generation and migration.

3.3 Study of Cambrian and early Ordovician carbonate sequences (Thorntonia Limestone, Mungerebar Limestone, Arrinthrunga Formation, Ninmaroo Formation) has revealed the widespread occurrence of an evaporitic lithosome which recurs in time. The former presence of ancient evaporites is recognised by the occurrence of silicified pseudomorphs after halite, anhydrite, and gypsum, including 'cauliflower' chert. The original partly evaporitic nature of these units is significant because it implies the presence of brines which were available to scavenge and transport metals. Research in the McArthur Basin shows a close association between carbonate units with evaporite imprints and sedimentary sulphide accumulations. Modern analogues of these ancient environments are currently being studied by the Baas Becking Geobiological Laboratory in Spencer Gulf.

3.4 Anomalous Pb, Zn, and Ba have been found in carbonates equivalent to the Thorntonia Limestone in GSQ Mount Whelan No. 1. High Pb occurs in the Red Heart Dolomite in BMR Hay River No. 11A. Anomalous Zn, Ba, and F have been found near Digby Peaks in the Burke River Structural Belt: average values of these elements in the Ordovician Swift Formation were anomalous compared with other units, and concentration is probably due to weathering.

3.5 Middle Cambrian black shale units in the Hay River area are host to three phases of anomalously high metal concentrations, each related to disconformity. In the earliest phase there is enrichment in Cr, Cu, Ni, Zn, V, Mo, Th, U, Sb, Au, and Pd. The two later phases indicate enrichment in Cr, Cu, Zn, V, Mo, and Ba.

3.6 The petroleum prospects of the Georgina Basin have been improved by the results of a major seismic survey which has confirmed and defined the Mirrica-Ethabuka Structure in the Toko Syncline area. This structure has a minimum vertical closure of 700 m over a minimum area of 130 km^2, and lies adjacent to the Toomba Fault, a high-angle reverse fault in this area. Possible stratigraphic traps are located on the northeastern flank and along the axis of the syncline.

3.7 Black shale units of Middle Cambrian age in the Hay River area are potential petroleum source rocks, having a relatively high organic carbon content. Equivalent strata occur in the Toko Syncline.

3.8 Residues of hydrocarbons are present as bituminous interparticle pore infillings in the Ninmaroo Formation of the Toko Range and the Burke River Structural Belt. The thermal history of this formation, as indicated by conodont colour alteration, is between 60-140 ^{o}C in the Toko Range, and 50-90 ^{o}C in the Burke River Structural Belt. A projected thermal maturity gradient based on GSQ Mount Whelan vitrinite reflectance analyses indicates the area around Carlo and further south in the Toko Syncline is prospective for liquid hydrocarbons to a depth of 3250 m.

3.9 Several lines of evidence suggest that the Hay River area, along the southern margin of the Georgina Basin has undergone a thermal history which has important implications for the discovery of liquid petroleum in this, and perhaps adjacent areas.

Pyrobitumen (mesophase) has been recovered from black shales in the Hay River coreholes - and from the Lower to Middle Cambrian Red Heart Dolomite. It has also been recognised in equivalent strata in PAP Netting Fence No. 1 where some kerogen partings have high reflectivities and exhibit the general characteristics of an 'anthracitic' vitrinite or low reflectivity inertinite. The pyrobitumen is thought to have formed at temperatures of about 220°C. Confirmation of localised regional heating within the Hay River - Desert Syncline area is given by the presence of doubly terminated quartz crystals in the Red Heart Dolomite. These contain fluid inclusions consisting of saline water in immiscible relationship with hydrocarbon gas. A realistic growth temperature is considered to be about 250°C.

3.10 A thin oil shale interval has been discovered in BMR Mount Isa No. 1 adjacent to the Barkly Highway. Black shales in a dominantly carbonate sequence are thought to represent the feather edge of the Inca Formation which now becomes prospective. Organic carbon values for this formation in BMR Duchess No. 14 are close to 5%.

3.11 A significant contribution to knowledge of the tectonics of the Georgina Basin is the recognition of the probable existence of thrust fault 'scales' ('squamose' faults). In the south-west Georgina such faults are normal at one end, become thrust faults in their middle course, and terminate in monoclinal structures as they curve generally to the northwest, e.g. the Toomba-Craigie Fault system (terminating in the Marqua Monocline) and the Hay River lineaments. Having tentatively recognised such fault systems, one can postulate that they may extend beneath the superficial deposits of the Simpson Desert as possible petroleum traps.

3.12 With the completion of palaeontological analysis of the late Cambrian carbonate sequences in the Burke River Structural Belt, a biochronological framework, based on trilobites, is available for this area. Late Cambrian time in such environments in this area is now characterised by twenty assemblage zones. Since this interval has a duration of 20 m.y., each assemblage has an approximate duration of one million years. Such a fine biochronology permits a more accurate dating of Cambrian events, and the reconstruction of a more detailed palaeogeography.

An early Ordovician conodont biochronology is now established for the carbonate sequences (Ninmaroo Formation) of the Burke River Structural Belt and Toko-Toomba Ranges (Coolibah Formation), and for the predominantly clastic sequences of the Toko-Toomba area and Dulcie Range. Seven successive conodont assemblages are recognised in the Ninmaroo Formation of the Burke River area; four are present in the Kelly Creek Formation in the Toomba Range; and two further assemblages occur in the Coolibah Formation.

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