Controls of mineralisation in the Featherbed Volcanics, northeast Queensland

Felsic volcanic rocks and related granitoids associated with caldera-collapse structures or ring complexes have long been recognised as prospective areas for a variety of mineral deposit types, notably in the western USA. Igneibrite-dominated felsic volcanic rocks of late Palaeozoic age are widespread in eastern Australia, particularly in northeastern Queensland. The Featherbed Volcanics, 100 km west of Cairns (Fig. 7), are located in an intensely mineralised region, but were poorly known geologically and, until the recent upsurge in gold exploration activity, had seen little mineral exploration.

In 1982, BMR, in collaboration with the Geological Survey of Queensland and James Cook University of North Queensland, began research on the Featherbed Volcanics and associated intrusive rocks with the objectives of determining if and how they are related to the extensive known mineralisation, and locating the most prospective sites for undiscovered mineral deposits.

The Upper Carboniferous to Lower Permian Featherbed Volcanics cover an area of about 3000 km² at the northern exposed end of the Tasman Fold Belt. The volcanic rocks are mostly confined to a composite volcano-tectonic subsidence structure made up of at least six (possibly nine) overlapping or juxtaposed collapse structures which appear to young to the northwest. The volcanics and associated intrusives comprise two main groups:

- **Upper Carboniferous I-type rocks**, which crop out on the southern and western sides of the Featherbed complex and in a sag structure in the southeast, and
- **Lower Permian A-type rocks**, which are mostly confined to an eroded composite caldera-collapse structure — or cauldron (Fig. 7).

**Upper Carboniferous I-type rocks and associated mineralisation**

Rocks in and around the southeastern sag structure include andesite to rhyolitic ignimbrites, minor andesite lava, and intrusive rocks of an equivalent compositional range. The thickness of the volcanics in the sag structure is uncertain, but is probably 200–500 m. Upper Carboniferous rocks west of the main cauldron include rhyolitic and dacitic ignimbrites and granodioritic to granitic intrusives. I-type characteristics of these rocks include relative abundance of mafic compositions, ubiquitous biotite, very common hornblende, common pyroxene, and metaluminous to mildly peraluminous compositions moderately high in MgO, CaO, Sr, Ni, and Cr and low in Pb.

Mineral deposits in the Upper Carboniferous I-type rocks are mainly Sn, W, Mo, and base metals, and are particularly concentrated in and around the southeastern sag structure. However, work by students at JCUNQ shows that Upper Carboniferous granites associated with Sn-dominant mineralisation to the south and southeast of the area studied in this project appear to be of A-type character. W–Mo deposits at Wolfram Camp and Bamford Hill on the eastern side of the main cauldron, and at Scardsons Top Camp on the western side are related to high-level plutons of intensely fractionated I-type biotite leucogranite dated at about 300 Ma. Some of the gold detected on the western side of the main cauldron may also be related to Upper Carboniferous I-type intrusive rocks, but that at Red Dome is related to a rhyolitic plug chemically more akin to the Lower Permian A-type rocks.

**Lower Permian A-type rocks and associated mineralisation**

Rocks within the main cauldron, and some of those between its northeastern margin and Mount Mulligan (Fig. 7) are mainly crystal-rich rhyolitic ignimbrites, with minor rhyolite lava around the margins; intrusive rocks range from granodiorite to granite, the most common being porphyritic micro granite which forms a discontinuous ring around the magma bodies. The I-type volcanic rocks are up to 600 m thick, and the total preserved thickness must be at least 1 km in places; the original thickness may have been twice that. Limited isotopic dating indicates a Permian age for these, and are characterised chemically by low MgO, CaO, V and Cr, and high Ba, Pb, Zr, Nb, Y, rare earths, Zn, Sn, W, Ga, and Ga/Al₂O₃, relative to the Upper Carboniferous I-type rocks.

Known mineral deposits in these rocks are limited to sparse base-metal, Au, U, minor W, and possibly Sn. Base-metal and tin deposits at Dover Castle are hosted by Lower Permian A-type volcanic rocks, but may be genetically related to a granitic intrusion in the mineralised area dated as earliest Permian. Tin and minor tungsten in the Koorkoorba area, between the southern end of the Fernleigh and the Tennessy Ring Dyke, may be related to the Late Carboniferous magmatism, but could equally well be related to the Early Permian A-type magmas.

**Implications of contrasting emplacement styles**

One interpretation of the foregoing data is that the Upper Carboniferous rocks (and their country rocks) are inherently more prospective, particularly for Sn, W, Mo, and base-metals, than the Lower Permian rocks. The Upper Carboniferous volcanic rocks are much less voluminous and include a much greater proportion of mafic to intermediate rocks than the Permian volcanics, implying that their magma bodies were probably more mafic and therefore denser than those related to the main cauldron. The I-type parent magmas were probably also relatively more hydrous, and this combination of properties would have resulted in their being initially emplaced at shallower levels (before appreciable fractionation) at deeper levels than the A-type magmas. The greater depth of emplacement would account for the sagging of the relatively thick roof of the magma chamber during and after magma withdrawal, rather than wholesale caldera collapse. Extensive fractionation — from dioritic (or perhaps gabbroic) to granitic compositions — resulted in extensive concentration of fluids and ore metals, and the development of hydrothermal systems.

Their composition and volume indicate that the Permian rocks originated from much larger, mainly granitic magma bodies which — because of their lower density, higher temperature, and probably fluoric-rich, relatively anhydrous nature — are likely to have been emplaced at higher levels than the I-type plutons; indeed, there is abundant evidence of extensive intrusion into very high levels in the volcanic pile itself. As a consequence of this high-level intrusive activity, caldera collapse would have been more likely than it would for the deeper-level I-type intrusive activity. Also, eruptions are likely to have been more voluminous, and fractionation, concentration of ore-forming metals, and generation of hydrothermal systems significantly more limited.

**Exploration potential**

Apart from emplacement style and chemical composition, other factors should be taken into account when assessing the exploration potential of the Lower Permian A-type rocks. A-type granitoids are apparently associated with much of the Sn-dominant mineral deposits in the Herberton–Irvingbank–Emuford region, southeast of the Featherbed Volcanics (Pollard, 1983; Witt, 1985; Johnston, 1986: all PhD theses, JCUNQ), and there is considerable evidence that A-type rocks generally are favourable host and/or source rocks for Sn and Climax-type porphyry Mo deposits (White & others, 1984: Geology of granites and their metallogenetic relations. Part 3: geochemistry. Proceedings of the international symposium, Nanjing University, Nanjing, China, 26–30 October 1982, 737–751). The southeastern lobe of the Featherbed Volcanics and the region to the southeast appear to be more deeply eroded than the main Featherbed cauldron, where favourable ore-depositional environments may not yet have been uncovered. Finally, there are extensive
areas of hydrothermal alteration — mainly propylitic and sericitic, but also argillic and other types — in the main Featherbed cauldron, particularly around the margins and in areas of structural disturbance in the interior.

Thus the Lower Permian A-type rocks which make up the majority of the Featherbed Volcanics, and which might appear an unattractive exploration target, are actually at least as prospective as the Upper Carboniferous I-types, but for a different range of metals and different styles of mineralisation. The I-types are prospective for W-dominant and base-metal mineralisation — the A-types for Sn-dominant mineralisation, base-metals, U, and possibly Mo; both appear to be prospective for Au, the concentration of which is probably more a function of the existence of long-lived hydrothermal circulation and favourable deposition of chemical character of associated (source of metals, fluids and/or heat) igneous rocks.

For further information, contact Dr Doug Mackenzie (Division of Petrology & Geochemistry) at BMR.

**Pedin**

BMR's national petroleum exploration data index

Pedin, which is being developed by BMR's Petroleum Branch, contains basic information on petroleum exploration drilling and geophysical surveys in Australia and its territories. The database was designed and implemented in 1984 with the support of a NERDDP grant. Additional NERDDP support has been provided for further development of the database in 1987.

The main objective of the project in 1987 is to develop software to facilitate the use of the database both within and outside BMR. Reporting formats are being designed to present the data in a form of most general use to the exploration industry. Additional reporting formats will also be added, and reports will be produced to meet specific requirements.

Full implementation of the database will facilitate petroleum exploration and research on a national basis. It will be central to the development of modern computational techniques and systems for petroleum resource assessment in BMR.

Pedin contains data on PSSA and P(SL)A wells and geophysical surveys. It also contains information on BMR geophysical surveys, and some geophysical information on post-subsidy onshore wells and surveys. It will be the most comprehensive database of its kind in Australia.

Data on wells entered into Pedin include well location (co-ordinates, map sheet areas, basin, States, and permit areas), dates of drilling, equipment, operator, references to well completion reports, information on samples collected and their storage location, drilling objectives, and results (including stratigraphic information). Geophysical survey entries include survey location, basic information on survey parameters, techniques and equipment, and summaries of results and interpretations from survey reports.

Pedin's software is implemented on BMR's HP 1000 computer using the HP/IMAGE 1000 DBMS, and is now being transferred to BMR’s new mainframe computer, a Data General MV/20000 with an ORACLE DBMS. Open-file data stored in Pedin on the Data General system will be available for general access.

Information on the Pedin database will be published, and the database will be demonstrated to a number of government and petroleum exploration organisations later in 1987.

For further information, contact Mr John Moss at BMR.

**Recent publications and data releases**

Since the publication of the last issue of the BMR Research Newsletter (October 1986), BMR has released the following publications and data (up to 15 February 1987).

**Publications**

**Reports**
- 248 - Investigation of the characteristics and source of the Magnetic Ridge anomalous coffar, Cobar, NSW.
- 249 — Application of geophysics to exploration for heavy mineral sands deposits.
- 276 — Review of Cambrian and Ordovician palaeontology of the Amadeus Basin.
- Australian Mineral Industry Quarterly (Vol. 38, Nos. 3 & 4).

**Maps**
- 1:100 000 geological maps: 5757/pt 1756, Devils Marbles region; 5856/pt 5857, Kurundu region; 5955/pt 5855p 6055, Elko region.
- 1:20 000 preliminary geological map: Murni Munni layered intrusion.
- 1:100 000 magnetic domains map: S150 Albany.
- 1:500 000 geology: Australia.

**Recorded releases on open file**
- 1985/43 — A proposal for ODP-drilling on the Australian continental margin in the Obway Basin/west Tasmania region.
- 1985/63 — VALAL and ASSAD: two programs for estimating and summing undiscovered petroleum sources.
- 1985/64 — Australia's potential for further petroleum discoveries (from May 1986).
- 1987/1 — First order regional magnetic survey of PNG, March/April 1985.

**Release of data**

**Airborne geophysical maps**
- 1:250 000 78 maps, showing either magnetic properties, magnetic contours, radiometric contours, or flight-line systems (in all States).
- 1:100 000: two maps showing radiometric contours (Tasmania).

**Digital data**
- Digital point-located airborne magnetic data for five 1:250 000 sheet areas (WA and SA).

**Marine geophysical data**

**Lord Howe Rise** — in general, may be obtained by contacting BMR's Information Service (telephone 02 499620 or 02 499623).

BMR's assessment of EOR potential in Australia

An enhanced oil recovery (EOR) project is being carried out by BMR with a NERDDP grant. The project is designed to provide a detailed assessment of Australia's petroleum resources which may be derived by enhanced recovery methods.

One of the objective of the project are to identify the most likely petroleum fields in Australia with prospects for the application of EOR techniques, and to assess the amount of additional oil which may be recovered using various improved recovery techniques at selected oil-pricing levels.

Oil-bearing reservoirs that appear to be most suitable for the application of improved recovery techniques will be selected with the aid of a basic screening process. Screening of reservoir information already collected for publication in BMR's Australian Petroleum Accumulations Report series will assist in the selection of possible suitable reservoirs in the early stages of the EOR project. Later information on all major EOR activities carried out from May this year will be sought from the petroleum industry for particular fields and reservoirs selected for study. The Centre for Petroleum Engineering Studies at the University of New South Wales will collaborate in the EOR project by providing computer-modelling expertise, and by carrying out detailed simulation studies of the selected reservoirs. A consultant with many years experience of the petroleum industry from the United States will assist the year of the year the project will also be employed on the project.

The EOR project is the first such detailed study of prospective methods for improving the recovery from Australia's petroleum reservoirs. The study will highlight the potential value of EOR to Australian petroleum production. In particular, consideration of economic factors in the study will provide guidance to the petroleum industry on the potential of any given application of EOR compared with drilling new fields. It will also provide additional information for a better quantitative assessment of Australia's petroleum resources for use in strategic planning and policy evaluation by industry and governments.

Information on all major EOR activities carried out from May this year will be published under the terms of the NERDDP grant. The confidentiality of detailed information provided by the petroleum industry will be maintained.

For further information, contact Mr Brian McKay (Resource Assessment Division) at BMR.

**IEA EOR conference**

In September of this year, officers from BMR's Petroleum Branch, in conjunction with the International Energy Agency (IEA), will organise a three-day meeting in Sydney on enhanced oil recovery (EOR). A two-day field excursion to visit Bass Strait offshore production facilities will follow the Sydney meeting.

The meeting, sponsored annually by IEA, will be attended by representatives from ten nations; BMR is the designated lead agency for Australia. EOR research by the member nations covers four task areas through research at

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