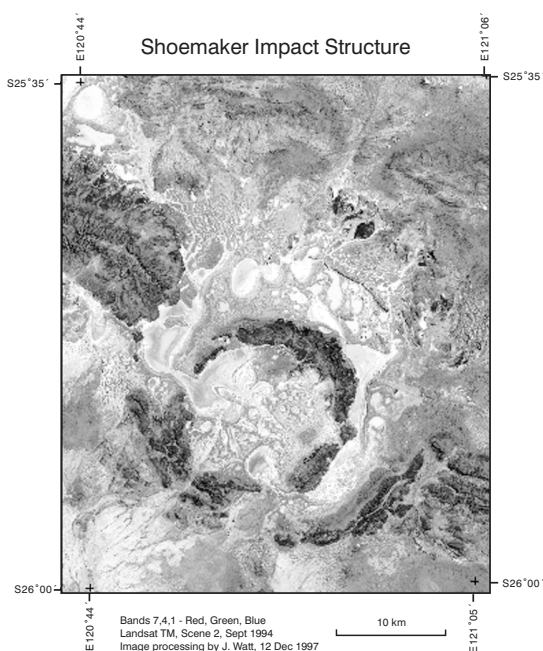


Shoemaker Impact Structure — GSWA renames Teague Ring Structure after Eugene Shoemaker



The Shoemaker Impact Structure is the new name proposed by Franco Pirajno (GSWA) and Andrew Glikson (previously with AGSO, now with Geospectral Research in Canberra) for the Teague Ring Structure.

The Shoemaker Impact Structure, 110 km northeast of Wiluna, was discovered in 1969 by Hadyn Butler (University of New England), who recognized it as being the result of a bolide (meteor or comet) impact. The structure was further investigated by GSWA geoscientists in the 1970s as part of the regional mapping of the NABBERU 1:250 000 geological map. They considered it to be a cryptoexplosion crater — a circular structure formed by violent degassing of a volatile-rich magma. However, a number of diagnostic criteria indicate that the structure is the result of an impact, either of a meteorite or a comet. These criteria include planar features in mineral grains and shatter cones in rock outcrops. Shatter cones are known to be uniquely diagnostic of bolide impacts.

With the start of GSWA's new mapping project in the Proterozoic Earaheedy Basin in

1997, the Shoemaker Impact Structure was re-examined. The structure is about 30 km in diameter and straddles the boundary between the southern margin of the Earaheedy Basin and the Yilgarn Craton. Parts of the structure were mapped in detail by Eugene and Carolyn Shoemaker (USGS) in 1985 and 1995. In 1996 Franco Pirajno and the Shoemakers decided to combine their efforts in the study of the structure, and during the 1997 field season Franco mapped the entire structure at 1:25 000 scale.

Tragically, Eugene Shoemaker died in a car accident on 18 July 1997, near Alice Springs. Eugene and his wife Carolyn were on their way to Western Australia where they had intended to continue their landmark work on Australian impact structures, including the former Teague Ring Structure. Eugene Shoemaker was a great geoscientist of international reputation and a pioneer in the study of bolide planetary impacts. The opening sentence in one of his many obituaries reads: 'Gene Shoemaker died with his boots on in the red heart of Australia, a man in motion, looking for craters, his mind alive and probing to the last'.

The Shoemaker Impact Structure is a complex, possibly multi-ring, crater with a central uplift of Archaean crystalline rocks. The rocks of the central uplift are shattered and contain thin veins of impact-generated melt. The crater itself consists of inward- ▶

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FIELDNOTES

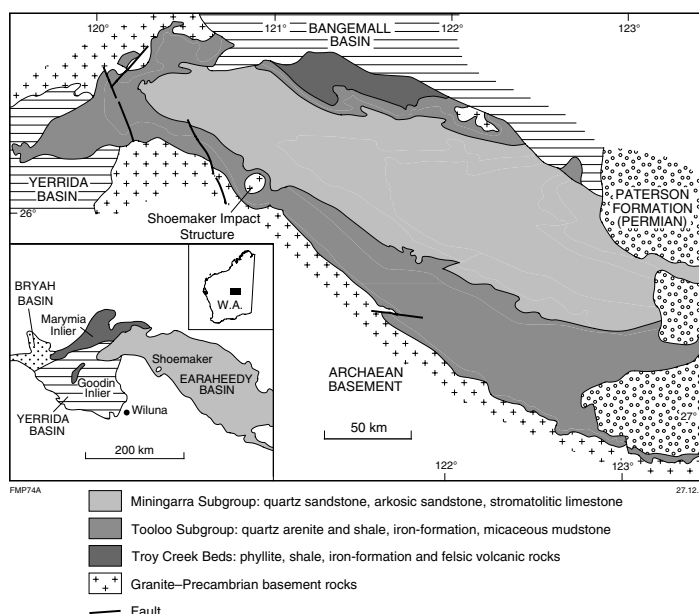
► dipping, locally upturned sedimentary rocks of the Earraheedy Group. Shatter cones and other striated structures are found in these rocks.

The age of the structure is not well constrained. Age determinations by GSWA geoscientists indicate that the Shoemaker Impact Structure formed sometime between 2027 and 1630 million years ago.

Estimates of the size of the bolide are fraught with difficulties and must take into account parameters such as density, mass, velocity, and angle of impact. A rule of thumb is that a crater can be 25 times the diameter of the impactor. If this rule is applied, then the impactor that produced the Shoemaker crater was about 1.2 km in diameter.

In Australia there are at least 21 recognized impact structures (about 140 are known world-wide). There is no doubt that more will be discovered in Australia and world-wide as a result of continuing detailed geological and geophysical investigations. Of the 21 Australian impact structures, nine are in Western Australia with the Shoemaker Impact Structure being the largest and oldest. Curiously, many of the impact structures in WA fall in a straight, northeasterly trending line extending across the State (see Australia's Meteorite Craters by Bevan and McNamara, published by the WA Museum).

Heavy bombardments by bolides occurred early in the geological history of all planets, and appear to have steadily decreased with time, both in frequency and size. The Earth did not escape impacting; in fact it is recognized that our planet must have received a greater impacting flux than the moon, owing to its greater gravitational attraction. It is estimated that there have been more than 200 impacts from bolides, forming structures larger than 1000



Regional geology around the Shoemaker Impact Structure.

km in diameter, between 4500 and 3800 Ma. These would have been basin-sized impacts, which would have influenced, if not determined, the geological evolution of the planet.

Impacts are transient and very high energy events. The average velocity is about 10 km/s (range 5–45 km/s). In comparison, the muzzle velocity of a bullet is about 1 km/s. It is calculated that the energy released by a 10 km-diameter meteorite is equivalent to about 100 million megatonnes of TNT, which is in fact far greater than the most powerful earthquake (equivalent to only 1000 megatonnes of TNT!).

Depending on the diameter of the bolide, the resulting effects on the point of impact and surrounding region can be far-reaching, environmentally disastrous, and may cause mass extinctions. The 65 Ma Manson Impact Structure in the USA is 35 km in diameter and was caused by a two km-diameter meteorite. The effects of the blast covered more than half of the USA. It is interesting to note that the Manson structure was, at first, also considered to be a cryptoexplosion crater.

Impact events can also be important for the emplacement and/or modification of ore deposits. In fact, there is a substantial body of evidence to suggest that economically important mineral deposits owe their existence, directly or indirectly, to impacting events.

Many questions remain unanswered about the Shoemaker Impact Structure, such as the type and size of impactor, precise age of impact, original depth of the crater, and the effects of the impact on the mineralization present in the Earraheedy Basin. A joint study by Franco Pirajno, Carolyn Shoemaker, Joe Plescia (NASA), and Andrew Glikson is underway to further our knowledge of this fascinating structure. The NABBERU 1:100 000 geological map, on which the Shoemaker Impact Structure is found, is being compiled and publication is expected in 1999. □

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A standard format for the digital reporting of geochemical and drillhole data

Each year more than 3000 mineral exploration reports are submitted by explorers to the Department of Minerals and Energy (DME). These reports contain detailed information on exploration programs carried out on tenements including geophysical surveys, geochemical sampling, and drilling results. In 1997 reports included logs for more than 160 000 diamond, RC, and RAB holes (7.7 million metres drilled) and assays for about 450 000 surface samples.

The information is generally submitted as hard copy (text, tables, plans). Only 10–15% of reports are accompanied by digital files, mainly geophysical survey data. As most of the information in the reports originated in digital form, DME is investigating how the submission of digital data could be significantly increased. Benefits for industry are obvious and ultimately include open-file data that is easier to use. A number of issues are currently under consideration, mainly relating to validation, archiving, and release of digital data. Draft guidelines for the submission of digital data are expected to be circulated for industry comment within the next few months.

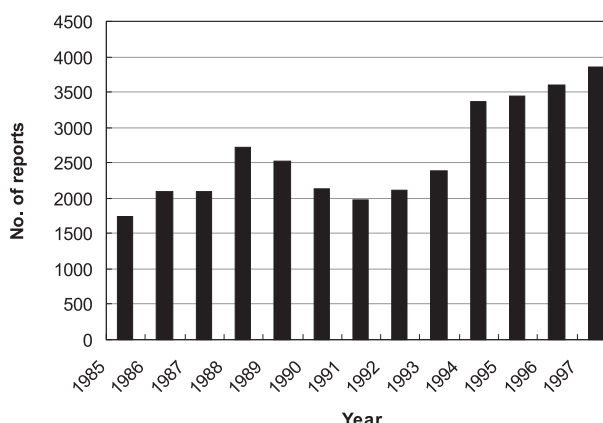
To further increase the usefulness of digital data that are likely to be submitted to DME in future, data models have been developed for a number of geological themes (geology, geochemistry, drilling, mineral resources). These go beyond a straight ASCII format by defining sequences, relationships, and contents of individual fields and tables to allow direct comparison and merging of datasets from different sources. The

models have been developed in Microsoft Access and include a data dictionary.

This project has been carried out through AMIRA (Australian Mineral Industries Research Association) and is sponsored by AGSO, all mainland Geological Surveys, and two major mining companies. The list of sponsors points to another important benefit — it is the intention of all States to eventually accept data in this format for statutory reporting purposes.

The project is currently in its final stage, which involves testing of the model outside the sponsor group. The aim is to prove that existing data can be accommodated within the model without loss of information, and that data can be transferred using the model. A cost-benefit analysis for the adoption of the model by both government and industry will also be carried out. A number of mining companies, large and small, have expressed their interest in being used as guinea pigs. The tests will be carried out within the next few months.

Number of statutory mineral exploration reports received by DME from 1985–1997



If the last stage of the project is successful, the data model will be adopted as the preferred format for data submission for statutory geochemical and drillhole data, which constitutes the bulk of information within company reports (geophysical data has not been included as standard formats already exist).

At this stage it is not intended to make the use of the model compulsory, but rather to encourage industry to adopt it. In this context, promotion and education will play an important part. The benefit of using the model will be increased with every company that chooses to adopt it. Currently, about 500 companies and individuals submit data to DME every year. A common format for digital files will allow easy data transfer between companies and DME, which translates directly into savings of time and money. □

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Mineral Occurrences Program: fostering exploration activity

The GSWA's Mineral Occurrences Program aims to enhance the perceived prospectivity of Western Australia by producing geoscience packages for WA by concentrating on large, geologically integrated regions or terranes. These packages will consist of a geology and mineralization map with details on the mineral occurrences, an explanatory report, and a user-friendly digital dataset.

Promotion of the mineral prospectivity of Western Australia has the broad goals of:

- ◆ further fostering exploration activity, particularly in 'green-fields' terranes;
- ◆ increasing the State's resource inventory by facilitating new discoveries and reducing risks in exploration; and
- ◆ diversifying the State's resource base to include a wider range of mineral commodities, particularly copper, lead, zinc, platinum-group metals, and ferro-alloys.

Products

The project will result in four distinct, though related, products:

- ◆ A Geographic Information System (GIS)-based exploration activity index for WAMEX open-file statutory reports (spatial activity index). Information will be sourced from open-file company reports. The specific areas of exploration activities will be included under the headings listed in the Table.
- ◆ The mineral occurrence attribute database (WAMIN), which is part of the GSWA WAROX field database, and contains spatial information on minerals, as well as details of occurrence form and type, host rocks, alteration character, and commodities.
- ◆ A GIS-assisted synthesis of the mineral exploration activity data, geological map data, mineral occurrence data from the WAMIN database, and geophysical, geochemical,

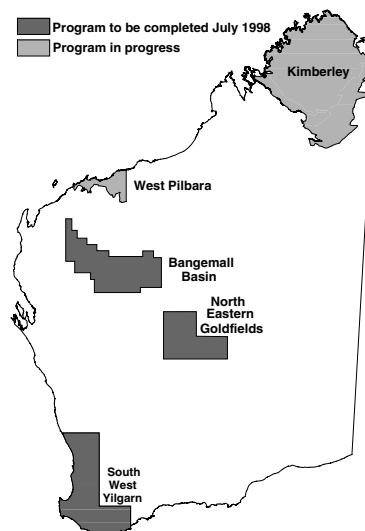
geographical, and where available, satellite imagery will be published as ArcInfo or MapInfo files on a CD, with software to facilitate viewing the data for those without the more sophisticated computer mapping tools.

- ◆ A printed geological map showing all known mineral occurrences with marginal tables detailing the mineral occurrences, and an accompanying report that will include details of minerals, characteristics and models for each area of mineralization.

What work is involved?

The following work is carried out as part of the mineral occurrences program:

- ◆ systematic 'data mining' of statutory reports listed in the WAMEX open-file database and other sources for data on exploration activity and mineral occurrences;
- ◆ digitizing spatial information and entering standardized data into GIS-compatible attribute databases;
- ◆ adding value to that data by field validation of selected mineral occurrences;
- ◆ combining and verifying spatial and attribute information, obtained from the above and from other sources including Landsat and airborne geophysics, in a GIS environment to identify regional controls of mineralization and exploration potential.



Exploration Activity Index

The present WAMEX database can only be searched spatially on 1:50 000 sheet areas, on the outer coordinates of a group of tenements, or on locality or project names. It is not possible to search spatially on the actual areas in which different exploration techniques have been carried out. To counter this, a GIS approach has been used so that the areas of activities shown in Table 1 can be identified, together with textual information concerning the activity.

Mineral occurrences

A *mineral occurrence* is defined as an accumulation in bedrock or regolith of an economic mineral exceeding an agreed concentration and size. *Mineral deposits* are the subset of mineral occurrences with probable economic value. *Ore deposits* are the subset of mineral deposits that can be

developed at a profit. Large numbers of accurately located mineral occurrences, therefore, provide a wealth of information on regional and local controls of mineralization.

Much effort is spent on accurately locating as many historic mine workings as possible. Although in some areas, the Differential Global Positioning System has been used to provide mineral occurrence locations to better than 10 m accuracy, the typical accuracy of mineral locations is ± 100 m.

Product release

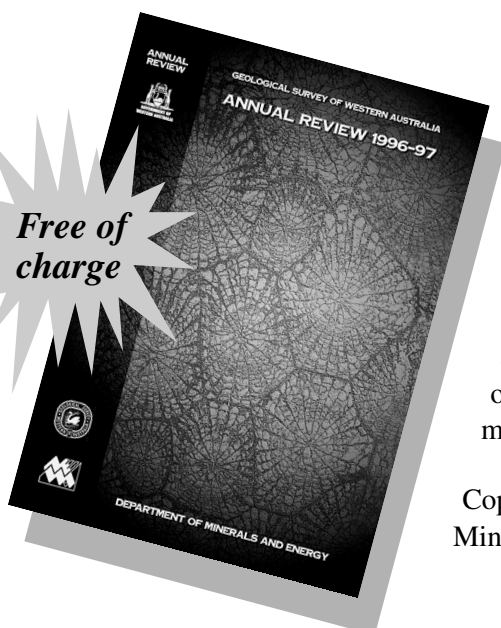
Work is underway on mineral occurrences packages for the Bangemall Basin, northern Eastern Goldfields, southwest Yilgarn, west Pilbara, and Kimberley regions. Products will be available for the first three areas in 1998. ☐

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Types of mineral exploration techniques

ACTIVITY ACRONYM	DESCRIPTION
ACH	Airborne geochemistry
AEM	Airborne electromagnetic surveys
AGRA	Airborne gravity surveys
AMAG	Airborne magnetic surveys
ARAD	Airborne radiometric surveys
DIAM	Diamond drilling
EM	Electromagnetic surveys (includes TEM, Sirotem, etc.)
GEOL	Geological mapping
GEOP	Other geophysical surveys (includes IP, resistivity, etc.)
GRAV	Gravity surveys
HYDR	Groundwater surveys
LSAT	Landsat TM data
MAG	Magnetic surveys
NGRD	Non-gridded geochemical surveys (includes chip, channel, dump, and gossan)
RAB	RAB drilling (includes other shallow geochemical drilling such as auger)
RAD	Radiometric surveys (includes downhole logging)
RC	RC drilling
REGO	Regolith surveys (includes laterite, pisolite, ironstone, etc.)
RES	Resistivity
ROT	Rotary drilling (predominantly percussion drilling)
SEIS	Seismic surveys
SOIL	Soil surveys
SSD	Stream sediment surveys



GSWA ANNUAL REVIEW 1996-1997

The 1996-1997 GSWA Annual Review contains feature articles, which present discussions of issues and events of importance or interest during the year under review, technical summary papers on aspects of the Survey's current programs with preliminary findings of ongoing research, and a review of individual projects that make up the total GSWA program.

Copies are available from: Information Centre, First Floor, Mineral House (details on back page).



Regolith Geochemical Mapping Program in its fifth year

The GSWA's Regional Regolith Geochemical Mapping Program, which commenced in 1993/94, aims to provide information on the distribution of the regolith and its chemistry in order to assist mineral exploration in Western Australia. This includes identifying metallogenic provinces, which may have potential for mineralization, and complementing regional geological mapping. The program was initially directed towards the goldfields and the northeastern part of the Yilgarn Craton, but subsequently the focus has turned towards the Proterozoic basins and the Kimberley region.

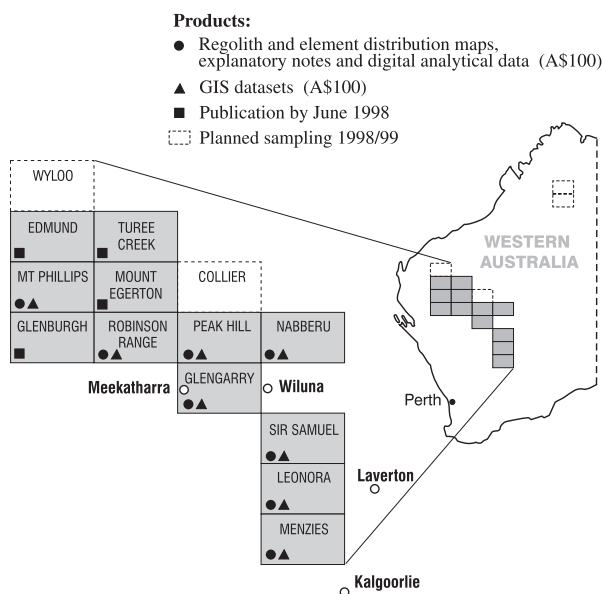
To date, explanatory notes have been published for eight 1:250 000 sheets including MENZIES, LEONORA, SIR SAMUEL, PEAK HILL, GLENGARRY, ROBINSON RANGE, NABBERU, and MOUNT PHILLIPS. Packages soon to be released include MOUNT EGERTON, TUREE CREEK, GLENBURGH, and EDMUND.

In 1998 GSWA will accelerate the program with the publication of four new packages from the western part of the Proterozoic Capricorn Orogen, and field sampling of four further sheets in the Capricorn and Kimberley regions.

During 1998 rapid sampling of the four sheets will be undertaken using helicopters. This follows the very successful 1997 field program, which pioneered the extensive use of helicopters for regional-scale regolith sampling. 'Operation Desert Storm' and 'Operation Winter Tempest', as the programs were named, involved the use of helicopters to transport pairs of geologists and field assistants to collect more than 4000 regolith

samples. Helicopter sampling of a 1:250 000 sheet takes around 12 days, which is much more efficient than vehicle sampling. The project involves a team of 20, including geologists, field assistants, pilots, and engineers.

The four map sheets planned to be sampled in 1998 are COLLIER, WYLOO, DIXON RANGE, and GORDON DOWNS. Each sheet will have its



own set of geological and logistical problems. For instance, distributing helicopter fuel and locating base camps may be difficult on the WYLOO sheet, as parts of the area are very rugged with few suitable access tracks.

The main outputs from the regional regolith geochemical mapping program are the production of a regolith materials map from a combination of remotely sensed data and ground observation, and the analysis of regularly spaced regolith samples for most major and trace elements. In addition, in 1998 the Geological Survey will trial the collection of gravity data at each regolith sample site.

Sampling is carried out at a nominal density of one sample per 16 km², with the preferred sample medium being stream sediment, although soil and sheetwash samples are taken in areas lacking well-defined drainage. At each location a sample of the 0.45–2 mm fraction is collected and this is analysed for up to 50 major and trace elements. At each sample site information on the regolith and local geology is recorded, which is used to interpret the chemistry and assist in construction of the regolith materials map. In addition to the regolith map and element concentration maps, special plots of integrated remotely sensed geochemical data, sample geochemical data, regolith pH, and conductivity are produced.

In order to understand the relationship between bedrock mineralization and regolith, there has been increased emphasis placed on statistical treatment of the data. This has taken the form of element indices that are indicative of certain types of mineralization including chalcophile, base metal, and pegmatite.

Explanatory Notes including hard copy maps and a disk with digital sample data are available from the Department of Minerals and Energy Information Centre. The dataset with maps is also available in GIS format (ArcInfo, ArcView, or MapInfo). The Explanatory Notes and the GIS dataset each cost \$100. □

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Bush Telegraph

Geological Survey's expertise in demand

Amadeus Petroleum NL has called on the services of Geological Survey geologist, Mark Stevens, to assist them in their exploration drilling program in the Officer Basin. Amadeus, as title holder of petroleum exploration permit EP 380 in the Savory Sub-basin, had a commitment to drill three exploratory wells before the end of 1997. These were to be the first deep wells in the sub-basin since GSWA's Trainor 1, and would be continuously cored.

As part of the Geological Survey's Petroleum Initiatives program, the Interior Basins Team had been concentrating on unravelling the petroleum potential of the poorly understood Officer Basin. A team of Survey geologists has examined the Officer Basin sequence in the field and has continuously cored two wells, Trainor 1 and Empress 1A. At Amadeus' request Mark

Stevens was seconded to them to sit their wells as part of a government/industry exchange program. Mark has been involved with the drilling and core description of the two Survey wells and is co-author of a number of reports on the basin, so was well equipped for the job.

The Amadeus drilling program commenced in October 1997 and ended in December with the satisfactory completion of all three wells. As part of the cooperative agreement this valuable new contribution of data will be turned over to the public domain ahead of the regulatory confidentiality period and the cores will be available for inspection by interested parties, alongside GSWA's Empress and Trainor cores.

As part of the exchange, Henry Moors, who was contracted by Amadeus, was seconded to work in the Interior Basins Team while Mark was on the rig site. Henry has contributed to GSWA projects in the

Yowalga and Savory Sub-basins whilst with the Survey and we look forward to including his contributions in scheduled GSWA publications.

Petroleum Initiatives program update

The Interior Basins Team, which is part of the Geological Survey's Petroleum Initiatives program, is currently studying the Empress 1 and 1A drillcores, from the Yowalga Sub-basin of the Officer Basin. In 1998 the Team are looking forward to a very busy field season in the Yowalga and Waigen Sub-basins of the Officer Basin. In the Waigen Sub-basin a major geophysical project, which will be a semi-detailed gravity survey, and a stratigraphic test hole are planned. Members of the Team will also be attending and presenting papers at the Western Australian Basins Symposium in August. □

Did you know ...?

Western Australian geology on CD

We have now released Geological Data Packages on CD for three 1:100 000 map sheets (SIR SAMUEL, DARLOT, and DUKETON – see back page for details). We are now preparing a Geological Data Package for State coverage (1:2 500 000 scale), so watch for release announcements either in future editions of FIELDNOTES, or in the GSA (WA) monthly newsletter WAG.

Regolith geochemistry program hits the spot

There has been a lot of interest in our regolith geochemical-mapping program.

In response to industry questions such as 'when will the next sheet be released?' we have undertaken to announce the release date of each new sheet in the Business section of The West Australian a few days before release. By doing so, we feel we are giving all interested explorers equal opportunity to get hold of these packages as soon as they are released.

And we have had buyers waiting on the doorstep on the day of release!

So if you have an interest in our regolith geochemical mapping program, watch The West for announcements on the release of packages on the TUREE CREEK, GLENBURGH, MOUNT EGERTON, and EDMUND 1:250 000 sheets as the financial year draws to a close. □



SOME RECENT PUBLICATIONS

Permian stratigraphy and palynology of the Carnarvon Basin, Western Australia

REPORT 51 by A. J. Mory and J. Backhouse

Includes stratigraphy/palaeontology map \$40.00

Structural interpretation and hydrocarbon potential of the Giralia area, Carnarvon Basin

REPORT 52 by A. Crostella and R. P. Iasky \$35.00

Program 2 — Industry support : Geological Survey Plan for 1997–98 and subsequent three years

RECORD 1997/1 \$20.00

Compilation of SHRIMP U–Pb zircon geochronology data, 1996

RECORD 1997/2 by D. R. Nelson \$25.00

Stratigraphic revision of Palaeoproterozoic rocks of the Yerrida, Bryah, and Padbury Basins (former Glengarry Basin)

RECORD 1997/3 by S. A. Occhipinti, K. Grey, F. Pirajno, N. G. Adamides, L. Bagas, P. Dawes, and G. Le Blanc Smith \$20.00

Compilation of whole-rock geochemical data for the King Leopold and Halls Creek Orogens

RECORD 1997/4 by S. Sheppard, T. J. Griffin, and I. M. Tyler \$40.00

Industrial minerals in Western Australia — the situation in 1997

RECORD 1997/5 by J. M. Fetherston, P. B. Abeyasinghe, and W. A. Preston \$25.00

Archaean geology and mineralization of the northern part of the Eastern Goldfields Province, Yilgarn Craton, Western Australia — a field guide: Kalgoorlie '97

RECORD 1997/7 compiled by S. Wyche \$20.00

Geology and mineralization of the south-central Yilgarn Craton, Western Australia — a field guide: Kalgoorlie '97

RECORD 1997/8 compiled by W. K. Witt \$20.00

EXPLANATORY NOTES

Geology of the Isabella 1:100 000 sheet by I. R. Williams and A. F. Trendall

Map and explanatory notes \$20.00

GSWA ANNUAL REVIEW 1996–1997 *free of charge*

REPRINTS OF 1:250 000 GEOLOGICAL SERIES MAPS

(Previously out of print)

DONGARA – HILL RIVER (SH 50-05, SH 50-09)

map only \$10.00

LAVERTON (SH 51-02)

map only \$10.00

YALGOO (SH 50-02)

map only \$10.00

MARBLE BAR (SF 50-08)

map only \$10.00

SIR SAMUEL (SG 51-13)

map only \$10.00

1:100 000 GEOLOGICAL SERIES MAPS

BANJAWARN (3242) — First edition plot by T. R. Farrell

map only \$10.00

BOYCE (3238) — First edition plot by S. F. Chen

map only \$10.00

GEOPHYSICAL MAPS

East Pilbara Total Magnetic Intensity images, 1:100 000 scale

price per image \$300.00

EASTERN CREEK (3054); **MUCCAN** (2956);

NULLAGINE (2954); **MOUNT EDGAR** (2955)

MISCELLANEOUS PUBLICATIONS

Schedule of petroleum exploration wells — Bonaparte and Browse Basins by J. Haworth

hardcopy and digital data \$100.00

GEOLOGICAL DATA PACKAGES ON CD

Geological data packages are now available for three 1:100 000 sheet areas. Themes available and prices vary from sheet to sheet. Data are in ArcInfo, ArcView, and MapInfo formats.

Themes	SIR SAMUEL	DARLOT	DUKETON
Outcrop geology	✓	✓	✓
Solid geology	✓	✓	✓
Regolith materials	✓	✓	-
Regolith geochemistry sample data	✓	✓	-
Index to open-file exploration data	✓	-	-
Mineral resource data (MINEDEX)	✓	-	-
Price	\$200	\$150	\$100

Products are available from:



Information Centre
First Floor, Mineral House
100 Plain Street, EAST PERTH 6004
Telephone (08) 9222 3459
Facsimile (08) 9222 3444