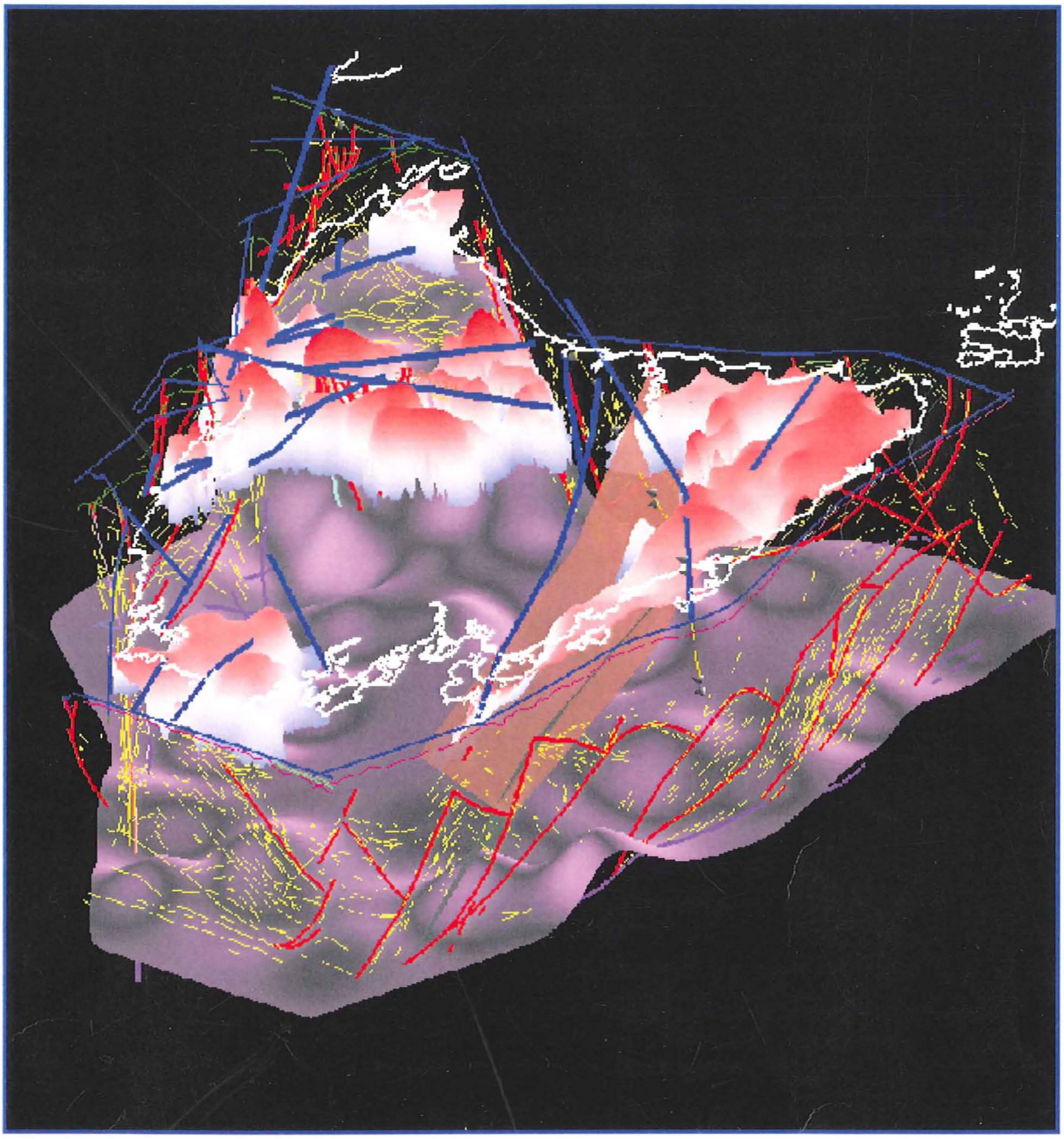
The Geological Framework of Tasmania



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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Symposium Abstracts — June 2001 —

MINERAL RESOURCES TASMANIA

Tasmania

DEPARTMENT of INFRASTRUCTURE, ENERGY and RESOURCES

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Australian Geological Survey Organisation
Mineral Resources Tasmania

The Geological Framework of Tasmania

— Abstracts Volume —

A workshop to finalise the TASGO and TASMAP Projects under the National Geoscience Mapping Accord
Elizabeth Street Pier Functions and Conference Centre, Hobart, 13–14 June 2001

Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601
Mineral Resources Tasmania, PO Box 56, Rosny Park, Tasmania 7018

PROGRAM

Wednesday 13 June — Structure of Tasmania

09:30–10:30	Registration, morning tea, poster display viewing	
10:30–11:00	The stratotectonic elements of Tasmania	C. R. Calver and D. B. Seymour
11:00–11:30	Obtaining new information on Tasmania's deep crustal structure from a 3-D wide-angle seismic experiment	N. Rawlinson, C. D. N. Collins and B. J. Drummond
11:30–12:30	The crustal structure of Tasmania based on deep seismic reflection profiling	R. J. Korsch, B. J. Drummond, A. V. Brown and T. J. Barton
12:30–13:00	Nature of the Crust in Tasmania	B. J. Drummond, C. D. N. Collins and T. J. Barton
13:00–14:00	*Lunch*	
14:00–14:30	Towards constructing a three-dimensional geological model of Tasmania	AGSO and MRT
14:30–15:00	The 1999 NGMA airborne geophysical survey — what's in them for us?	R. G. Richardson
15:00–15:30	Increasing gold prospectivity in the west Tamar region, northern Tasmania	A. R. Reed
15:30–16:00	*Afternoon tea*	
16:00–16:30	Apatite fission track thermochronology of Tasmania	B. P. Kohn, P. B. O'Sullivan, A. J. O'Sullivan and A. J. W. Gleadow
16:30–17:00	Structural geology of Hunter, walker and Robbins Islands and Woolnorth Peninsula, northwest Tasmania	M. Hall
19:00–19:30	*Drinks before workshop dinner (at Conference Centre)*	
19:30	*Conference Dinner*	

Thursday 14 June — Age Constraints

09:30–10:00	SHRIMP U-Pb zircon dating. A. Crystallisation ages of Tasmanian granites, and their significance	L. P. Black
10:00–10:30	SHRIMP U-Pb zircon dating. B. Inherited and detrital zircon age patterns in Tasmania, and their significance	L. P. Black
10:30–11:00	U-Pb zircon SHRIMP dating of Palaeozoic magmatism in northern Victoria Land and the South Tasman Rise; inferences for correlation with Tasmania	A. M. Fioretti, L. P. Black, R. Varne and D. Visona'
11:00–11:30	*Morning tea*	
11:30–12:00	The geochemistry of Tasmanian Devonian–Carboniferous granites and implications for the composition of their source rocks	M. P. McClenaghan
12:00–12:30	Age and structure of the Arthur Lineament, northwest Tasmania and King Island	O. Holm, R. Berry and D. Steele
12:30–13:00	Open session on significance of new data	
13:00–14:00	*Lunch*	
14:00–14:30	Mineral systems — enhanced prospectivity	G. R. Green
14:30–15:00	Integrated data sets for enhanced prospectivity	MRT
15:00–15:30	*Afternoon tea*	
15:00–16:00	Open discussion	

Preface

A. V. Brown[1], B. J. Drummond[2] and R. J. Korsch[2]

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2: Australia Geological Survey Organisation, Canberra

The TASGO Project was established in 1994 as a joint program, using multidisciplinary geoscientific and remote sensing techniques, and undertaken as part of a National Geoscience Mapping Accord (NGMA) program conducted by Mineral Resources Tasmania (MRT) and the Australian Geological Survey Organisation (AGSO).

The project was undertaken in order to define:

- the geological framework and fluid paths which constitute Tasmania;
- to test tectonic models of Tasmania used to constrain strategies for exploration for minerals; and
- to relate the results of the tests to detailed geological mapping being undertaken by Mineral Resources Tasmania, much of it at 1:25 000 scale, so as to define areas for future work.

The rationale for the project was the need for new conceptual models for the mineral deposits and tectonic formation of Tasmania so as to attract new investment and mineral explorers to Tasmania.

The TASGO project had a number of components:

1. Existing mapping by MRT was used to constrain a time-space diagram in which the basement elements of Tasmania were defined, and their stratotectonic history summarised.
2. New SHRIMP geochronology was used to provide better age constraints for the geological evolution of Tasmania.
3. Three deep seismic experiments were undertaken in and around Tasmania to map the structure of the basement elements at depth:
   - Five deep seismic reflection profiles, totalling 134 line kilometres of data, were acquired onshore at various locations throughout Tasmania.
   - Offshore circumnavigation of the island by AGSO's *Rig Seismic* recording 1758 km of deep seismic data.
   - During the reflection profiling by *Rig Seismic*, a refraction, wide-angle reflection and tomography experiment was conducted. Thirty-three portable AGSO recording systems were deployed onshore and, together with six University of Tasmania Observatory fixed stations, were operated continuously to record seismic arrivals from the air guns on *Rig Seismic*.
4. Researchers from a number of Australian and overseas universities co-operated with the TASGO Project by aligning their research with the goals of the project.

A follow up project, TASMAP, has included new aeromagnetic coverage onshore, and additional geochronological work.

This workshop presents a summary of the results of outstanding work of the TASGO and TASMAP projects. Some of the results have already appeared in the press, or been presented at an earlier workshop in 1998. Presentations at this workshop place special emphasis on integrating all results, from all disciplines, through an interactive computer-based three-dimensional image of the geology of Tasmania to upper mantle depths.

It is intended that all work undertaken for the TASGO and TASMAP projects, including that presented at both the 1998 and present workshops, will be published as a combined MRT/AGSO publication.

The stratotectonic elements of Tasmania

C. R. Calver and D. B. Seymour
Mineral Resources Tasmania

The 1995 TASGO geological synthesis divided the pre-Tasmania Basin geology of Tasmania into seven fundamental crustal elements, which may now be reassessed in the light of subsequent work.

The oldest exposed rocks are marine, mainly shelf-facies quartzarenite-pelite sequences. These units have broadly similar detrital zircon age spectra and are probably all broadly correlative and younger than c. 1200 Ma, perhaps late Mesoproterozoic or early Neoproterozoic. They are overlain by younger Neoproterozoic successions, which can be broadly correlated between elements. On King Island, a basal diamictite with a Marinoan cap dolomite (c. 600 Ma) is succeeded by mafic rift volcanic rocks and picrites. In the Rocky Cape Element, the base of the Neoproterozoic sequence is Torrensian (c. 750 Ma) based on correlation with the Adelaide Geosyncline. Mafic rift volcanic rocks, of within-plate affinities, similar in age to those of King Island, occur higher in the sequence; a similar succession overlies Oonah Formation in the Dundas Element. In the Tyennan and Adamsfield–Jubilee Elements, mafic rift volcanic rocks are absent, and the Neoproterozoic successions are dominantly dolomite resting with gently angular unconformity on the older quartzitic successions.

The Proterozoic elements of western Tasmania are apparently not terranes of widely separate origins. They were probably all part of the same passive margin in the Neoproterozoic, which underwent rifting at c. 600 Ma. The elements then re-amalgamated about 100 Ma later, in the Early to Middle Cambrian Tyennan Orogeny, coeval with the Delamerian and Ross Orogenies in neighbouring parts of Gondwana.

King Island is affected by the 760 Ma Wickham Orogeny, for which there is little evidence in mainland Tasmania. However, there is no compelling reason for a fundamental crustal boundary between King Island and northwest Tasmania. The eastern boundary of the Rocky Cape Element is defined by the Arthur Lineament, a narrow steeply-dipping blueschist-bearing zone of high strain and metamorphism that formed in the Tyennan Orogeny. East of the Lineament, it remains unclear whether the quartzose turbidites of the Oonah Formation correlate with the basal Neoproterozoic successions at c. 750 Ma, or with the older quartzitic successions, which could be as old as 1200 Ma. The Arthur Lineament has been re-interpreted by Turner and Bottrill (2001) as a major east-dipping Cambrian thrust zone, that transported the blueschist, the Oonah Formation and younger allochthons westward onto the craton — the blueschist having previously been extruded from a subducted wedge.

The Early Cambrian mafic-ultramafic complexes comprise fault-bounded lenses including exotic oceanic and forearc volcanic rocks. It is now commonly accepted that these were obducted westward onto a thinned, passive margin made up of the rifted Proterozoic rocks, at c. 510 Ma in the early part of the Tyennan Orogeny. Still unclear is what other parts of the geology might be allochthonous.

The true western limit of the Tyennan Element is concealed beneath younger sequences. The Tyennan Element shows structurally interleaved high-grade and low-grade metamorphic rocks, the highest grades indicating burial depths of over 30 kilometres. Metamorphism occurred in the early phase of the Tyennan Orogeny, c. 510 Ma, at about the same time as the emplacement of the ultramafic rocks and the metamorphism in the Arthur Metamorphic Complex. The metamorphic rocks were evidently unroofed shortly after metamorphism. Turner and Bottrill (2001) suggest that the high-grade rocks were emplaced at a high structural level, following extrusion from a west-dipping subduction zone, but seismic data suggest a shallowly east-dipping western boundary to the Tyennan Element, so it is now detached from any remnant of a west-dipping subduction zone, presumably by westward thrusting.

The boundary between the Tyennan and Adamsfield–Jubilee Elements may be a transition into unmetamorphosed Proterozoic rocks that are otherwise similar to the Tyennan Element. The concealed boundary between western Tasmanian rocks and the Ordovician–Devonian Mathinna Group of northeast Tasmania is constrained by drill hole data and is the basis for the 1995 element boundary. However potential field and seismic data show a significant boundary 20 km further west, within a package of east-dipping thrust slices involving Proterozoic, Cambrian and younger rocks. One implication is that west Tasmanian-type geology forms basement to the Mathinna Group, which is an extension of the Lachlan Fold Belt. The offshore seismic shows stretched, block-faulted continental crust beneath eastern Tasmania, interpreted as the rifted Proterozoic continental margin. Detrital zircon ages from a sample low in the Mathinna Group show a typical Lachlan Fold Belt pattern, with ages that are unlike any known Tasmanian sources. This suggests some distance between the Mathinna basin of deposition and the shallow-water west Tasmanian platform, where sediments were being shed from the Proterozoic elements at the same time. The present juxtaposition presumably occurred by Devonian thrusting.

Reference

TURNER, N. J.; BOTTRILL, R. S. 2001. Blue amphibole, Arthur Metamorphic Complex, Tasmania: composition and regional tectonic setting. *Australian Journal of Earth Sciences* 48:167–181.

Obtaining new information on Tasmania's deep crustal structure from a 3-D wide-angle seismic experiment

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2: Australian Geological Survey Organisation, Canberra

The marine seismic component of the TASGO survey was completed in March 1995, when AGSO's research vessel *Rig Seismic* fired ~36,000 airgun shots at a 50 m spacing while circumnavigating Tasmania. In addition to recording normal-incidence reflection data (Drummond *et al.*, 2000), an array of 44 digital and analogue recorders were distributed throughout Tasmania to detect refraction and wide-angle reflection arrivals. Despite the limited range at which the airgun sources could be effectively recorded (usually <200 km), a lack of land-based shots, a number of recorder failures and low signal-to-noise ratios at several sites, sufficient data were obtained to make a tomographic-style inversion for crustal structure feasible.

The method of Rawlinson *et al.* (2001*a*) is used to invert refraction and reflection travel times for crustal structure. In this approach, structure is represented by sub-horizontal layers separated by smoothly varying interfaces. Within a layer, velocity varies linearly with depth but has no lateral variation. The justification for using such parameters is that reflection arrivals, especially from the Moho, are common features of the data. Reflection arrivals are more sensitive to variations in interface structure than refraction arrivals. In addition, the data coverage is not sufficiently dense to resolve the trade-off between interface depth and lateral velocity variation within a layer. The travel times can be satisfied by lateral variations in interface structure only, which suggests that the use of a more complex representation is not justified.

The principal inversion result considered here was obtained by using all picked P_mP (Moho reflection) and P_n (Moho refraction) travel times to constrain a two-layer model of Tasmania (Rawlinson *et al.*, 2001*b*), consisting of the crust and upper mantle separated by a Moho of variable depth. A total of 2590 travel times (2148 P_mP and 442 P_n) from 13 shot lines to 21 receivers is used in the inversion. Linear estimates of model resolution indicate that the solution model interface structure is well resolved except for the central and northeast regions of Tasmania. Average crustal and P_n velocities (velocity immediately below the Moho) of 6.2 km/s and 8.0 km/s respectively are also well resolved according to these resolution estimates. Key tectonic inferences from the Moho map include:

1. the Arthur Lineament metamorphic belt in northwest Tasmania overlies a major change in crustal thickness (over 5 km) and probably represents the northwest limit of deformation in Tasmania during the Mid–Late Cambrian Tyennan Orogeny;
2. thickening of the crust beneath central northern Tasmania may be associated with the juxtaposition of the Eastern and Western Tasmania Terranes during the Mid-Devonian Tabberabberan Orogeny; and
3. the thicker crust beneath the west coast is consistent with a margin formed by trans-tensional strike-slip motion along the Tasman fracture zone, while the thinner crust beneath the east coast is more consistent with extensional deformation associated with the stretching between eastern Tasmania, the East Tasman Plateau and the Lord Howe Rise, which occurred prior to sea floor spreading in the Tasman Sea.

The most dense coverage of TASGO wide-angle data occurs in northwest Tasmania, with sufficient crustal phases present to resolve shallower structure. In a separate inversion, 2401 refraction and reflection travel times were used to constrain the geometry of four crustal layers overlying the upper mantle in northwest Tasmania. Features of interest in the solution model include upward deflections of mid-upper crustal interfaces beneath the Arthur Lineament, and a lower crustal layer that lies above the Moho and pinches out in the vicinity of Three Hummock Island, a structure also imaged by the coincident reflection data (Barton, 1999). It is possible that this structure represents the remnants of underplated oceanic crust emplaced during a subduction event, e.g. westerly subduction beneath the Rocky Cape Element during the formation of the Mt. Read Volcanics in the Lower Palaeozoic. Despite significant structural variations within the crust, the Moho structure and average crustal and P_n velocities of this model accurately mirror that of the Tasmanian Moho solution discussed above.

References

BARTON, T. J. 1999. Crustal structure of northern Tasmania based upon a deep seismic transect, *in: Last conference of the Millennium.* 53:3–4. Geological Society of Australia.

DRUMMOND, B. J.; BARTON, T. J.; KORSCH, R. J.; RAWLINSON, N.; YEATES, A. N.; COLLINS, C. D. N.; BROWN, A. V. 2000. Evidence for crustal extension and inversion in eastern Tasmania, Australia, during the Neoproterozoic and Early Palaeozoic. *Tectonophysics* 329:1–21.

RAWLINSON, N.; HOUSEMAN, G. A.; COLLINS, C. D. N. 2001*a*. Inversion of seismic refraction and wide-angle reflection traveltimes for 3-D layered crustal structure. *Geophysical Journal International* 145:381–401.

RAWLINSON, N.; HOUSEMAN, G. A.; COLLINS, C. D. N.; DRUMMOND, B. J. 2001*b*. New evidence of Tasmania's tectonic history from a novel seismic experiment. *Geophysical Research Letters* (submitted).

The crustal structure of Tasmania based on deep seismic reflection profiling

R. J. Korsch[1], B. J. Drummond[1], A. V. Brown[2], T. J. Barton[1]

1: Australian Geological Survey Organisation, Canberra
2: Mineral Resources Tasmania

This abstract summarises the results of the TASGO deep seismic reflection profiles onshore and offshore Tasmania.

In western Tasmania, onshore Line 95AGS-T1shows that the eastern side of the Arthur Lineament dips to the east. In the vicinity of the Dundas Trough, the western basin-bounding fault and the Rosebery Fault dip to the east, whereas on the eastern side of the trough the Henty Fault dips to the west. These three faults form part of a hard-linked fault system. The Cambrian mafic-ultramafic package appears to consist of a stack of thin thrust slices.

Onshore Line 95AGS-T2 followed the Cradle Mountain Link Road. It crossed part of the Dundas Trough and Early–Middle Palaeozoic sedimentary rocks, with thin Tertiary basalt covering much of the area. The northern extension of the Henty Fault is imaged as a west-dipping fault under shallow basalt cover. Rocks of the Denison cycle are up to three kilometres thick, but appear to have been structurally thickened. They are underlain by the Bonds Range Porphyry which appears to have a sheet-like geometry more than one kilometre thick.

In northeastern Tasmania, onshore Line 95AGS-T3 was acquired to examine the geometry of the Mathinna Beds and the nature of the 'gold line'. A series of reflections dipping both to the east and west are interpreted to represent both east-directed and west-directed thrust faults.

Two shorter onshore lines, 95AGS-T4 and 95AGS-T5, were acquired across parts of the Tasmania Basin in an attempt to image the sedimentary pile and to determine whether images could be obtained across parts of the basin that contain dolerite sheets.

Prior to acquiring the offshore seismic reflection data, new aeromagnetic data were acquired for large regions of offshore Tasmania. These were merged with the onshore magnetic data and the resulting images were used to track structural and lithological features that had been mapped onshore into the offshore. The ship tracks were then positioned to cross the major Tasmanian basement element boundaries (Seymour and Calver, 1995) and other major geological features. Ignoring the Cretaceous–Cainozoic extensional basins imaged on some of the lines, the major features in the offshore basement are crustal-scale reflections that are predominantly east dipping. Thus, in western Tasmania the crustal elements appear to be bounded by east-dipping structures interpreted to be thrusts.

Acknowledgements

This work has been benefited through the input of many colleagues, including R. Richardson, D. Seymour, A. Reed, G. Green, C. Calver, M. McClenaghan and S. Forsyth (MRT), and J. Mifsud, M. Nicoll and A. Yeates (AGSO).

Reference

SEYMOUR, D. B.; CALVER, C. R. Tasmania NGMA Project. Sub-Project 1: Time-Space Diagram: Explanatory Notes. *Record Tasmanian Geological Survey* 1995/1.

The nature of the Crust in Tasmania

B. J. Drummond, C. D. N. Collins and T. J. Barton

Australia Geological Survey Organisation, Canberra

Rawlinson *et al.* (this volume) present a model of Moho topography based on the 3D tomographic inversion of seismic energy from airguns fired at sea and recorded on portable seismographs deployed onshore across Tasmania. In deriving the Moho model, Rawlinson *et al.* (2001) assumed that seismic velocity increases linearly with depth through the crust. This assumption is realistic for tomographic inversion studies because second-order velocity variations, should they occur, are unlikely to affect the estimated depths of the Moho in a significant way.

Seismic velocity is a good indicator of the composition of the rocks at depth. Seismic velocity increases with increasing mafic content, and with increasing metamorphic grade. Therefore the second-order variations that Rawlinson *et al.* (2000) were able to ignore would be an indication of variations in crustal composition and crustal type. The distribution of portable seismographs onshore across Tasmania was such that the derivation of detailed models of the variation of velocity in the crust, in 3D or even 2D, is not possible. However 1D models can be derived, and they allow a first-order classification of the types of crust in the basement elements of Tasmania.

Drummond *et al.* (2000) derived 1D models for the Proterozoic basement of southern Tasmania and the basement of Palaeozoic northeast Tasmania. Velocities in Proterozoic basement in southern Tasmania increase systematically with depth, from near 5.65 kms^{-1} below surficial sedimentary rocks, to 6.9 kms^{-1} at the top of a transition zone between the crust and mantle. The crust has a mid-crustal boundary between 8.8 and 11.5 km depth, across which the velocity increases from 5.9 to 6.25 kms^{-1}. The crust in this region is poorly reflective, and the Moho transition zone corresponds closely with the Moho interpreted in the coincident seismic reflection data along offshore seismic Line 148/01. These velocities and the poorly reflective crust are consistent with a crust of predominantly quartzo-feldspathic composition, with little or no mafic content. In contrast, the crust in the Northeast Tasmania Element, beneath the Mathinna Beds, has a lower crust made up of layers of rocks with relatively lower and higher velocities in the range 6.06 to 7.00 kms^{-1}. The crust in this region is highly reflective. The velocity structure and reflection character are consistent with layers of rock of quartzo-feldspathic nature alternating with layers with some but not high mafic content. Drummond *et al.* (2000) interpreted the structure and character of the crust in northeast Tasmania to imply that the crust had been highly extended before being partly shortened again.

Similar patterns of crust are interpreted in other provinces. The Proterozoic western and southern Tyennan Element and the Rocky Cape Element have crust similar to that in southern Tasmania interpreted from offshore Line 148/01. The lower crust of the Dundas Element is probably similar to that of northeast Tasmania; that is it has layers of lower and higher velocity rock, and is reflective in the seismic reflection profiles recorded onshore during the TASGO Project.

Seismic velocities in the crust in Tasmania appear to be low compared to global average values. The Proterozoic elements are particularly anomalous when compared with world average values; Proterozoic provinces elsewhere usually have thick crusts with high lower crustal velocities that indicate a large proportion of mafic rock. Proterozoic elements in Tasmania do not seem to have this mafic layer; this is an important consideration for models of granite genesis which require the partial melting of a mafic underplate, and for mineral system models which require mafic rocks.

References

DRUMMOND, B. J.; BARTON, T. J.; KORSCH, R. J.; RAWLINSON, N.; YEATES, A. N.; COLLINS, C. D. N.; BROWN, A. V. 2000. Evidence for crustal extension and inversion in eastern Tasmania, Australia, during the Neoproterozoic and Early Palaeozoic. *Tectonophysics* 329:1–21.

RAWLINSON, N.; HOUSEMAN, G. A.; COLLINS, C. D. N. 2001. Inversion of seismic refraction and wide-angle reflection traveltimes for 3-D layered crustal structure, *Geophysical Journal International* 145:381–401.

Towards constructing a three-dimensional geological model of Tasmania

AGSO and MRT

(R. J. Korsch, B. J. Drummond, M. G. Nicoll, A. V. Brown, R. G. Richardson, A. R. Reed, M. P. McClenaghan and J. L. Everard)

We have commenced building a three-dimensional geological model of Tasmania principally using the results of the TASGO deep seismic reflection data and the tomographic results of Rawlinson *et al.* (this volume) to constrain the geometry of Tasmania in the third dimension. Figure 1 illustrates one form of output from the model. In this figure, the upper surface of the model is based on DEM data defined in the texture, and the basement element defined by shades of grey. Other surface layers, e.g. geology, magnetics and gravity, can be draped across this surface. The model extends down to the Moho.

A preliminary attempt has been made to determine the 3D geometry of the major crustal elements of Tasmania, although this has been difficult to do in areas of limited data, such as beneath the Jurassic dolerite sills that cover much of the island.

Other features that have been incorporated into the model include the upper surface of the granitic batholiths, as interpreted from gravity data, and some of the major faults. On a more local scale, a first pass reconstruction of the Dundas Trough has been attempted using the surface geological map, the deep seismic reflection lines recorded onshore, and a series of geological cross sections constructed by R. F. Berry (1999, *Abstracts Geological Society of Australia* 53:6–7).

The model is being built using the GOCAD software and it is expected that it will evolve through time as new data become available.

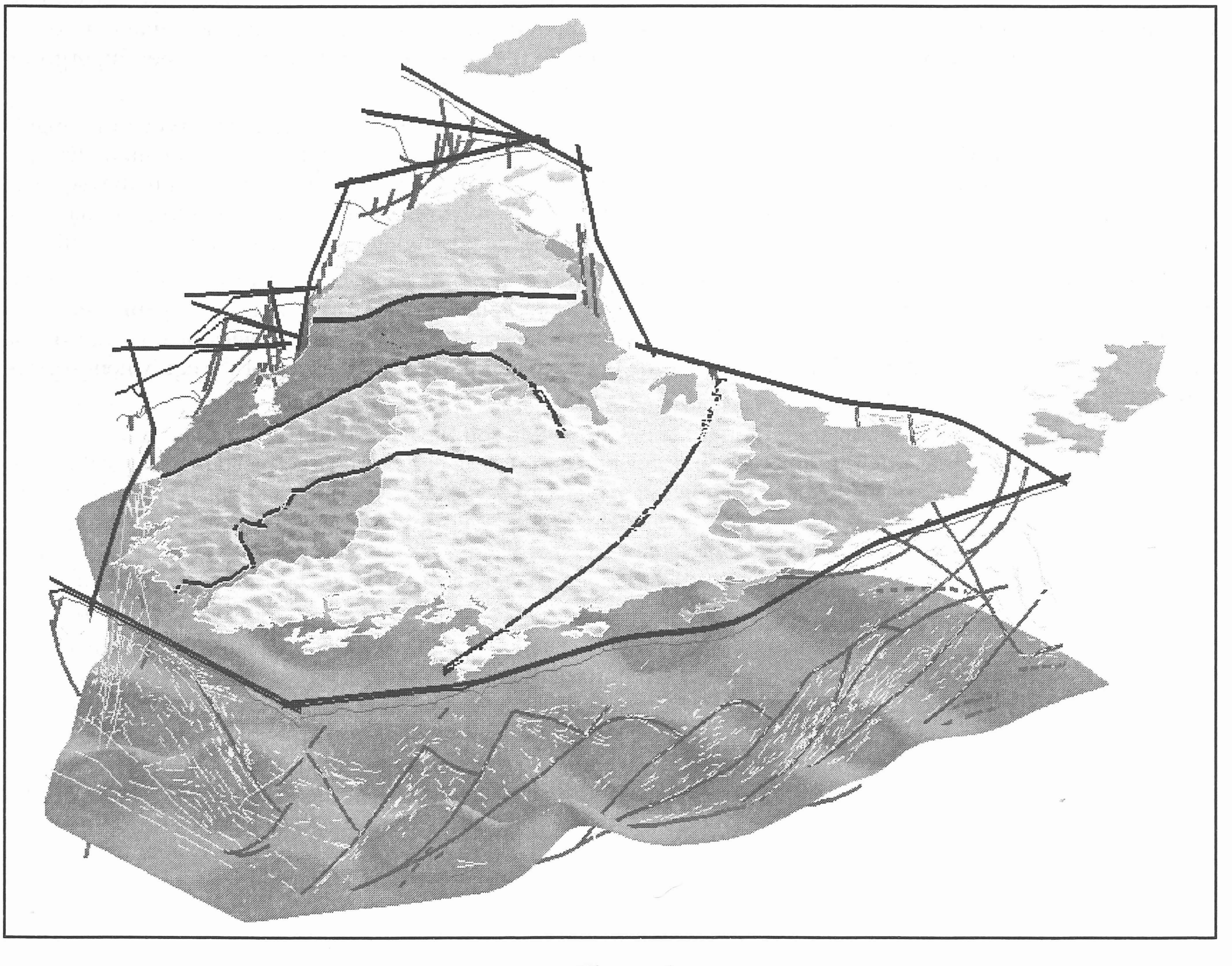

Figure 1

Three-dimensional image of the Tasmanian region showing the surface elevation, basement elements, topography of the Moho (after Rawlinson et al., this volume) and the interpretations of the offshore seismic reflection lines.

The 1999 NGMA airborne geophysical surveys — What's in them for us?

Robert Richardson

Mineral Resources Tasmania

In 1999 airborne geophysical surveys were flown over an area of central northern Tasmania and an area of the Tasmanian Midlands as part of a project under the National Geoscience Mapping Accord. The surveys provide the first fully calibrated aeromagnetic, radiometric and digital elevation data sets for Tasmania.

The radiometric data show no obvious vegetation-related artefacts and can be used effectively for lithological discrimination. In both survey areas the radiometric ternary image, independently displaying the equivalent surface distributions of potassium, uranium and thorium, differentiates between many of the outcropping rock types and provides valuable spatial data for geological mapping programs. Areas of Jurassic dolerite are characterised by depletion in uranium and thorium while rocks of the Upper Parmeener Supergroup are relatively higher in uranium than rocks of the Lower Parmeener Supergroup.

The magnetic data provide both structural and lithological information. The magnetic field in the central north Tasmania area is dominated by a large positive anomaly attributed to the Beaconsfield ultramafic body. When a sun-angle is used to enhance high frequency features the resulting anomalies correlate directly with the Jurassic dolerite and Tertiary basalt, and extensions of these rocks under younger cover are clearly visible. In the eastern part of the area the high frequency anomalies predominantly trend NW-SE but in the western part of the area there is little consistency in anomaly orientation. An arcuate magnetic anomaly north of Launceston is interpreted to be a dolerite cone sheet.

The magnetic data from the Midlands area define a series of polygons corresponding, in most cases, to the mapped Parmeener Supergroup rocks. The boundaries of the polygons correspond to either edges of Jurassic dolerite sills or to dolerite feeders. After enhancement of the high frequency features the data show that most of the area is underlain at shallow depth by dolerite. In only a few of the areas of outcropping Parmeener Supergroup rocks are the sedimentary rocks not underlain by dolerite at shallow depth.

What other information can be derived from these data? For the first time an aeromagnetic survey in Tasmania has adequately sampled the magnetic field produced by the Jurassic dolerite. By careful systematic modelling the anomalies from the dolerite may be accurately calculated in any models and any subtle magnetic anomalies sourced from deeper materials with lower magnetic susceptibilities will then become apparent. Combining the magnetic data with gravity and seismic data sets, where available, reduces the possibility of ambiguity during modelling.

The digital elevation model contains significant structural information and may also provide data to allow inferences to be drawn about recent geological history. The radiometric data provide a high quality input to geological mapping. Additional lithological discrimination is possible using ternary images of the ratio of the equivalent surface concentrations of each of potassium, uranium and thorium to the sum of the equivalent surface concentrations of all three elements.

Increasing gold prospectivity in the west Tamar region, northern Tasmania

Alistair Reed

Mineral Resources Tasmania

Analysis of geoscientific data compiled over the last five years and covering the west Tamar region in central-northern Tasmania is contributing to an increase in the total area considered prospective for gold. The data originate from a number of different studies, conducted at different scales, and from a number of different sources representing industry, federal and state government, and university groups. Data include regional seismic (TASGO), aeromagnetic and radiometric (TASMAP) surveys, 1:25 000 scale regional mapping, deposit- and outcrop-scale studies, and newly acquired petrological, geochronological, geochemical and ground-based geophysical data. Interpretation of these new data is being presented on 1:25 000 scale geological maps and is accompanied by explanatory notes. The objective in producing these maps is to encourage more focussed mineral exploration and to increase the chance of an exploration success in the region. Exploration success and responsible mining ultimately results in employment and generates income for industry, the government, and the community.

The geology between the Port Sorell embayment and the River Tamar is complex, comprising multiply deformed and interleaved successions of sedimentary, igneous and metamorphic rock of pre-Carboniferous age. These rocks are partly obscured by younger sedimentary and igneous successions. Pre-Carboniferous rocks have undergone at least two major orogenic events, culminating in the Tabberabberan Orogeny in the Early to Middle Devonian. The last phase of Tabberabberan orogenesis thrust Proterozoic and Palaeozoic rocks southwest, resulting in imbricate thrust stacking and duplication of the Palaeozoic rocks in the west Tamar region. This phase of Tabberabberan orogenesis is evident regionally and accompanied gold mineralisation throughout northeast Tasmania. However, it is most pronounced in the west Tamar region where it coincided with formation of Tasmania's largest mesothermal gold deposit, the Tasmania Reef.

The Tasmania Reef is located at Beaconsfield (50 km northwest of Launceston) and ranks in the top ten deposits in southeast Australia for both size and grade, with a pre-mining resource of about three million ounces. The reef strikes northeast, discordant to the predominantly northwest-striking stratigraphy. The deposit is thought to have formed when hot gold-bearing fluid ascended from depth via stratigraphically concordant, steeply northeast-dipping Tabberabberan-age thrusts. As the fluid flowed into the discordant Tasmania Reef it was exposed to rocks of varying composition. This appears to have affected the chemistry of the fluid leading to gold deposition. Identification of settings similar to that at Beaconsfield is critical to focussing regional exploration, however existing geological maps were of an inappropriate scale and insufficient detail to meet the needs of industry clients. New geological maps are currently being prepared that show prospective faults and stratigraphic contacts. These maps summarise the results of fieldwork by both industry and State geologists, and incorporate interpretation of regional aeromagnetic and radiometric data (industry geophysical and TASMAP data).

In addition to defining more prospective zones within Palaeozoic rocks, the new mapping is also showing a previously unrecognised westward continuation, into Proterozoic rocks, of thrust faults of the same age as those which acted as conduits for gold-bearing fluids at Beaconsfield. Microscopic examination of samples of Proterozoic rock collected from near these faults shows alteration and sulphide mineral assemblages similar to that associated with gold mineralisation at Beaconsfield. These rocks were previously accepted as being largely unprospective for gold and have received little attention from explorers. However, these rocks are of similar composition to rocks hosting gold mineralisation throughout northeast Tasmania and mainland southeast Australia. This, and identification of mineralised fault structures, clearly show that these rocks must now be considered as prospective for gold.

Finally, the seismic data show thrust faults of the same age and orientation as those at Beaconsfield, and elsewhere throughout the west Tamar region, penetrating the Earth's crust to depths greater than 20 kilometres. This is ideal for mineralisation, as large faults can access crustal-scale reservoirs of hot metalliferous fluids and facilitate their convection to surface. Focussing of fluids along such faults is more likely to produce larger and more economically viable mineral deposits. The existence of such structures associated with a region hosting Tasmania's largest mesothermal gold deposit is unlikely to be coincidence. Indeed, the combination of deeply penetrating, crustal-scale structures, proven mineralisation and a geology suitable for hosting gold mineralisation, makes the west Tamar region one of most prospective belts for gold in Tasmania, if not southeast Australia.

Apatite fission track thermochronology of Tasmania

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Tasmania is an ideal locality to study the low-temperature thermochronological imprint related to continental extension tectonics as it is surrounded by rifted margins. These include the Early Cretaceous failed rift to the north between mainland Australia and Antarctica, which at that time also included Tasmania, the middle Cretaceous to Palaeocene rift between Antarctica and Australia along the west coast, and the middle Cretaceous to Palaeocene rift between New Zealand and Australia along the east coast. The distance between Tasmania and its adjacent rifts is minimal due to very narrow continental shelves, hence any rift-related effects should also be evident onshore. To further record and quantify the onshore response related to the Cretaceous to Tertiary extensional tectonics of southeastern Australia, ~250 apatite fission track (AFT) analyses from a wide range of Precambrian to Cretaceous outcrop and subsurface rocks throughout Tasmania have been generated.

The results indicate that:

1. All AFT ages are younger than sample depositional, intrusive, or metamorphic age, and most are <120 Ma;
2. In many cases, the sampled rocks cooled rapidly from temperatures >~110°C to temperatures <~70°C at the time suggested by their AFT ages;
3. Tasmanian rocks record at least two regional cooling episodes; during the middle Cretaceous and the Palaeocene to Eocene; and
4. The rocks have continued to cool to present-day temperatures. There is also evidence for a third, more-localised episode of cooling during the Late Tertiary.

An episode of middle Cretaceous (between ~90–110 Ma) accelerated cooling is recorded through much of the eastern Tasmania highlands. This cooling was probably a response to kilometre-scale denudation following the onset of continental extension in the Tasman Sea at ~96 Ma. At several localities in eastern Tasmania, Permo-Triassic sediments presently exposed beneath (and intruded by) Jurassic dolerite, yield AFT ages which indicate rapid middle Cretaceous cooling from elevated palaeotemperatures ≥95°C. This cooling is recorded long after the emplacement of the dolerite, implying either that:

1. The shallow-level intrusion dolerite was deeply buried by an Upper Jurassic to middle Cretaceous sedimentary succession (>~2.5–4 km) which may have covered much of Tasmania prior to middle Cretaceous rifting; or
2. The dolerite was intruded at deeper levels (>2.5 km) than previously proposed and the entire overburden has subsequently been removed since the middle Cretaceous.

Based on field evidence, including localities where the Jurassic 'dolerites' were extruded as basalt, and evidence for thick accumulations of Upper Cretaceous to middle Tertiary sediment located offshore western Tasmania in the Sorell Basin system, we favour the first option.

A second episode of rapid cooling occurred during the mid Palaeocene to early Eocene (~50–60 Ma). Evidence for this cooling is restricted to eastern and western coastal areas, and throughout Flinders Island. We suggest that this phase probably records a far-field denudational response linked to an important spreading phase at this time in the Adare Trough to the south, which was related to initiation of major crustal extension and rift basin formation under the Ross Sea area. During this phase denudation rates in Tasmania peaked at ~50 m/m.y.

Localised cooling is recorded by many samples from the Flinders Island region, as well as from a few samples in northwest Tasmania. These samples characteristically contain a high proportion of very young single-grain ages <~15 Ma, suggesting that the rocks have recently experienced ~30–40°C cooling. Since the evidence for this cooling seems to be limited to the far north of the state, we propose that either:

1. Northern Tasmania experienced isolated fault reactivation related to Miocene neotectonics previously recognised along the southern margin of the Australian continent; or
2. Less likely, the reduced ages are due to hot fluid migration associated with a zone of elevated heat flow presently believed to be located beneath northeastern Tasmania.

In summary, AFT results from Tasmania indicate that the post-Palaeozoic thermotectonic history was significantly different than that previously inferred from regional geological observations. The data suggest that pre-middle Cretaceous, much of Tasmania was covered by a significant thickness of Jurassic–Lower Cretaceous sediments, which resulted in total resetting of the AFT clocks. Subsequently, Tasmania experienced at least two episodes of enhanced kilometre-scale denudation, during the middle Cretaceous and the early Tertiary. These episodes can be related to periods of extensional tectonics in the southeastern Australia region and to the south. The occurrence of young AFT ages on Flinders Island and along the northern Tasmanian coastline is either the result of Miocene tectonics within the Bass Strait area or, less likely, the result of recent localised hot fluid migration. Future studies in Tasmania extending this work will include mass balance calculations between inferred denudation volumes onshore with sedimentary volumes offshore and the application of the burgeoning apatite (U-Th)/He method to provide complementary information on the lowest temperature range that can be constrained by the apatite fission track system and even lower.

Structural geology of Hunter, Walker and Robbins Islands and Woolnorth Peninsula, northwest Tasmania

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Proterozoic rocks are excellently exposed near Woolnorth Point and around the coastlines of Hunter, Robbins and Walker Islands, just offshore from the northwest corner of mainland Tasmania. These rocks are correlated with the Rocky Cape Group and include dark coloured Lower Pelitics, probably equivalent to the Cowrie Siltstone, supermature, white quartzite, probably equivalent to the Detention Subgroup, and pale, multicoloured Upper Pelitics, probably equivalent to the Irby Siltstone. A very distinctive transitional unit, about 20 m thick, lies between the Lower Pelitics and quartzite and comprises interbedded black pelitics and grey-brown quartzite.

The backbones of the islands and peninsula are formed of quartzite, folded on Hunter Island and Woolnorth Peninsula and forming long, narrow strike ridges on Walker and Robbins Islands. The dominant structural trend, followed by the folds, faults and conspicuous, steeply-dipping slaty cleavage in the pelitic units, is N-S and is clearly outlined on aeromagnetic images.

The southern portion of Hunter Island is dominated by a large, asymmetric anticline with a very steep eastern limb. The western limb is disrupted by a narrow, quartzite-cored anticline bounded by very steep faults that dip towards the anticline and place quartzite against Upper Pelitics. Both faults have apparent reverse-sense displacement and the Upper Pelitics adjacent to each fault are folded into tight synclines. Three other large reverse faults were located on the west coast of Hunter Island south of Cuvier Bay, two of which enclose a 60 m wide strip of Upper Pelitics. Just to the west the remaining fault, dipping steeply east, separates vertical quartzite from similar rocks dipping moderately west.

The hinge zone of the main anticline extends south across Hunter Passage to Woolnorth Peninsula and north to Cuvier Bay. Northwards from the widest part of the island, quartzite and Upper Pelitics exposed on the eastern limb of the anticline are deformed into generally open mesoscopic folds. These are locally accompanied by west-dipping reverse faults and generally verge east. An exception is on the west coast north of Cuvier Bay where a steep, east-dipping reverse fault places west-dipping quartzite against folded Upper Pelitics.

In the hinge zone of the main anticline at Cuvier Bay quartzite dips west on the west side of the bay and east on the east side. Within the bay three strips of cleaved, mesoscopically folded Lower Pelitics are separated by two bands of quartzite at well exposed faults that dip towards the quartzite. These faults clearly exhibit normal sense displacement, but are parallel to both the large and small-scale structural features resulting from compressional deformation.

At the northern end of Walker Island at Love Bay a major fault dipping steeply west places quartzite, to the west, against Lower Pelitics. The quartzite dips gently east, with minor undulations and small thrust-related structures, and lies on the eastern limb of an anticline cored by Lower Pelitics. Vertical to slightly overturned Lower Pelitics east of the fault are overlain by quartzite on the east side of Love Bay.

The fault is also exposed near the northern tip of Robbins Island and lies within steep, east-dipping quartzite. Small open folds extend over a 10–15 m width immediately west of the fault, while strong fracturing in the quartzite dips moderately west. Lower Pelitics are exposed to southwest, along the western side of Robbins Island, and are folded into generally open structures.

The enigma of this fault is that it exhibits reverse sense displacement on Robbins Island and normal sense displacement at Love Bay, five kilometres to the north. Also uncertain is the age of all the faults described. The normal faults post-date the Rocky Cape Group, as no obvious facies or thickness changes were observed across them, while the reverse faults were clearly involved in the compressional deformation. Onshore and on islands along Robbins Channel, cleaved Late Cambrian sediments are involved in the N-S folds, and place a lower age constraint on the timing of deformation.

Because the normal faults are parallel to the compressional features and appear to have been involved in the compressional deformation, they are likely to have had their displacement sense reversed, at least along part of their length. They could range in age from Proterozoic to Late Cambrian, while their reactivation is most likely to have occurred during the late Early to Middle Devonian.

SHRIMP U-Pb zircon dating. A. Crystallisation ages of Tasmanian granites, and their significance

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On the basis of geological mapping and aeromagnetic imaging, pre-Late Carboniferous Tasmania has been divided into seven different stratotectonic elements. Each has a geological history and internal structure that is in at least some respects different from those of the other elements. SHRIMP U-Pb dating has been used to find the crystallisation ages of fifteen Devonian–Carboniferous granites (reported here) and to determine the age of their inherited zircon (reported elsewhere in this volume). Each of the studies helps better constrain the geological evolution of the individual elements.

The relative resistance of the U-Pb zircon isotopic clock to isotopic resetting is readily apparent from the new data, which show that previously obtained Rb-Sr and K-Ar mineral ages tend to be somewhat younger, even though emplacement was at a high crustal level where subsequent geological effects have been interpreted as being insignificant. There was a general progression of igneous activity from northeast to the west of Tasmania (including King Island) over about 50 million years (from the Early Devonian to the earliest Carboniferous). The youngest granites in northeast Tasmania are of comparable age to the oldest granites in the western elements. In the latter region, both I- and S-type granites (including Heemskirk red and Heemskirk white varieties) share a common age of about 360 Ma (although I-type granites also formed both earlier and later than this). It is possible that coeval I- and S-type activity had also occurred in northeast Tasmania, about 25 million years previously. The Grassy pluton on King Island yields a relatively complex array of individual zircon ages, consistent with it representing a second attempt at granite formation at 350 Ma. Whereas elevated temperatures about 10 million years earlier had generated substantial granite production in what is now west coast Tasmania, that event is interpreted to have been insufficiently intense to have produced more than localised partial melting in the King Island region at that time.

In northeast Tasmania, magmatic activity within the Blue Tier Batholith (BTB) lasted for about 23 million years. Unlike some of the previously reported Rb-Sr ages, all of the U-Pb zircon ages are consistent with field observations, which indicate that the hornblende-biotite granodiorites are older than the biotite granites, which in turn predate the alkali-feldspar granites. A large proportion of the zircon in a mafic enclave from The Gardens Granodiorite is of the same age as that in the host intrusive, an interesting observation, although not necessarily a diagnostic one for deciding between the competing models currently being used for Lachlan Fold Belt magma genesis. Igneous activity within the nearby Scottsdale batholith commenced about 10 million years after granite emplacement was initiated in the BTB, and probably also ended well before the emplacement of the youngest granite in the BTB (the latter conclusion is being tested by further dating). The new data support a previous conclusion, based on Rb-Sr geochronology, that the Lottah Granite is distinctly younger than the Poimena Granite, and that the two are genetically unrelated to each other.

A quantitative correlation between the presence or absence of regional foliation within the granites of northeast Tasmania allows the age of that deformation to be constrained at about 390 Ma.

A combination of the new U-Pb ages for the Tasmanian granites, previously reported (mainly K-Ar) dates from Victoria, and deep seismic evidence favours a previous juxtaposition of the two states in which the western boundary of northeast Tasmania would pass through with the Cape Liptrap region (to the west of Wilsons Promontory). A complementary study in Victoria to the granite inheritance patterns reported elsewhere in this volume for Tasmanian granites would prove invaluable for resolving this matter.

SHRIMP U-Pb zircon dating.
B. Inherited and detrital zircon age patterns in Tasmania, and their significance

Lance Black

Australian Geological Survey Organisation, Canberra

This constitutes the second of a two-part study to investigate the nature of the seven stratotectonic elements to which the pre-Late Carboniferous rocks of Tasmania have been assigned. The ultimate focus of this study is to glean as much information as possible about the nature of the deep crust below those elements, in the expectation that any such chronological information will complement the geophysical data. About half of the detrital zircon ages from the metasedimentary units were acquired during TASGO, several years ago. The remainder of the detrital ages and the zircon inheritance patterns for fifteen granites have been obtained over the past two years, as part of TASMAP. The rationale behind the latter part of the study is that granites source the deep crust, and are likely to transport refractory zircon crystals from there. As zircon is relatively resistant to the resetting of its U-Pb isotopic clock, it should preserve evidence of the age of that region.

Metasedimentary rocks (often of quartzitic composition) were collected from each of the seven different stratotectonic elements. A striking feature of these is the very similar detrital zircon patterns for all six of the westerly elements. Only the Tyennan sample has a signature that might be subtly different from the others. There is no evidence in that sample of any zircon younger than 1680 Ma, whereas zircon at least as young as about 1400 Ma has been found in the other westerly elements. This possibly indicates that the Tyennan element is older than the others, although it might merely reflect a sampling bias. There is no other chronological evidence to potentially distinguish between the six more westerly units. A dominance of 1700–1800 Ma zircon indicates that all of these rocks were primarily derived from Palaeoproterozoic source terranes. For all but the Tyennan sample, deposition definitely occurred after about 1400 Ma, and the presence of c. 1200 Ma zircon at some locations suggests an even younger limit. The Mathinna Group of northeast Tasmania yields a very different age pattern, which is dominated by 500–600 Ma detrital zircon. Less common is 800–1400 Ma zircon, while minor quantities of older (including Archaean) zircon are also present. The overall array is typical of comparable rocks in the Lachlan Fold Belt on the Australian mainland. The contrasting detrital age patterns between northeast and west Tasmania has enabled a controversy on the age of sediments in the Badger Head Block to be readily resolved.

In order to minimise the number of variables, inheritance patterns obtained during TASMAP were only determined for granites of Devonian–Carboniferous age. It is disappointing that far less datable inherited zircon was encountered in the granites than had been hoped for, and this reduces the degree of confidence of some of the conclusions. Nevertheless, several important observations can be made.

There is no evidence of different age components in the I- and S-type granites, although the former generally contain less inheritance. Neither is there any obvious difference between the inheritance in any of the six western elements, once again suggesting that these are at least broadly comparable. In contrast, there is a very pronounced difference between that array and the inheritance signature of the northeast Tasmanian granites. Importantly, the inheritance patterns within all the granites were found to closely mirror that within the rocks they intrude, to the extent that it is possible to tell whether or not a granite occurs in northeast Tasmania purely on its inherited zircon signature. Neoproterozoic granites in western Tasmania that were dated as part of TASGO have similar inheritance to their Devonian–Carboniferous counterparts, suggesting that the lower crust in that region did not significantly change over a 400 million year period.

The overall data are consistent with the three-component source model of Collins (1998), in which granites are interpreted as a mixture of new magma from the mantle, deep crustal material and parts of the tectonically-thickened overlying supracrustal sequence. From this assumption and the detrital and inherited zircon age patterns, it can be deduced that the deep crust beneath western Tasmania is considerably older than that below the northeast.

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U-Pb zircon SHRIMP dating of Palaeozoic magmatism in northern Victoria Land and the South Tasman Rise; inferences for correlation with Tasmania

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Tasmania and Northern Victoria Land (NVL), Antarctica, shared a common geological history until the Cretaceous rifting apart of eastern Gondwana. The exact pre-Cretaceous position of Tasmania relative to Antarctica is not yet well constrained (Veevers and Eittreim, 1988; Elliott and Gray, 1992). Nevertheless, the close geochemical and Sr isotopic similarities of granodiorites from northeast Tasmania with the Admiralty Intrusives in NVL suggest that both were derived from the same terrane. A U-Pb zircon SHRIMP investigation of the emplacement age and the inherited zircon component of selected Palaeozoic igneous rocks from NVL has been undertaken to test this hypothesis. Three granites from the South Tasman Rise (STR), an often overlooked piece of continental crust that might shed some light on the tectonic evolution of Tasmania, were also studied.

The Devono-Carboniferous Admiralty Intrusives (AI) and coeval Gallipoli Volcanics (GV) crop out in all three NVL Terranes, i.e. the Wilson (WT), Bowers (BT) and Robertson Bay Terranes (RBT).

Petrographic and geochemical similarities over a wide area suggest the AI share a similar source. They are mainly I-type, equigranular grey granodiorites with minor tonalites and locally abundant mafic microgranular enclaves. Only two plutons (Salamander and Yule Bay) show some minor differences. Previous K-Ar and Rb-Sr geochronology suggested that the AI represent an older magmatic episode, at around 390 Ma (outcrops in the eastern part of NVL), and a younger one at around 360 Ma (Fioretti *et al.*, 1997).

Five different plutons and three volcanic centres were dated to investigate this issue.

The Yule Bay and Tucker plutons (both in the RBT) belong to the hypothesised 'older' phase (380–390 Ma). Very similar crystallisation ages of around 365 Ma definitely rule out the old episode. Inferno Peak, which straddles the border between the RBT and BT, yields an indistinguishable age of 363 Ma. Mt Supernal and Mt Salamander, at the border between the BT and the WT, are slightly younger, with almost identical ages of 351 and 353 Ma. The Gallipoli Volcanics (GV) range in composition from basaltic andesite to dacite, with more abundant rhyolites at Gallipoli Heights. They are geochemically similar to the AI and were associated with the 'younger' magmatic episode of the AI. Our new data indicate that the NVL volcanism occurred at 370 Ma and at 356 Ma (Fioretti *et al.*, 2001).

Typical of most I type rocks, the AI and GV have very little inherited zircon, which makes their patterns very poorly defined. However, most of the AI samples contain zircon populations typical of the Lachlan Fold Belt (Williams *et al.*, 1992). The GV inheritance patterns are similar, except for Gallipoli Heights, which includes an Archaean signature. Although the crystallisation ages are significantly different, the inheritance patterns displayed by the AI are similar to the plutons in northeast Tasmania (Black, this volume), strengthening the idea that they originated from a similar source. However the consistently younger age of the AI argues against a direct link between NET and NVL.

Our main target in the STR was to ascertain the presence of Palaeozoic granites for correlation with neighbouring sectors. One of the three samples selected on geochemical and petrographic evidence comes from the east South Tasman Rise (ESTR); the other two were dredged from the western part of the south Tasman Rise (WSTR). The WSTR samples have identical Ross-Delamerian ages of 487 Ma and no zircon inheritance. The ESTR sample yields an age of 364 Ma. Its zircon inheritance pattern is similar to that of western Tasmania granites (Black, this volume), with ages between 1900 and 1400 Ma, and rare younger zircon. Its chemical composition is slightly different from west Tasmania granites, leaving some doubt on whether this rock represents a continental fragment of western Tasmania.

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The geochemistry of Tasmanian Devonian–Carboniferous granites and implications for the composition of their source rocks

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Because the composition of granites reflects that of their source (White and Chappell, 1977) the petrographic and chemical features of the Tasmanian Devonian–Carboniferous granites provide an indication of the nature of their source rocks in the mid and lower crust. The same features have been used to group the granites into twenty suites and the criteria of the restite model (Chappell and White, 1992) have been used to categorise them as being derived from sedimentary (S-type) or igneous (I-type) source rocks. Distinction has been made between those suites whose variation appears to have been produced by restite fractionation (unmixing) and those that appear to have shed their restite component and have undergone crystal fractionation. Petrographic features and approximate linear trends on two-element plots have been used as indicators of possible restite fractionation. Chemical criteria used to indicate crystal fractionation are Rb > 250 ppm, Sr < 50 ppm and Ba <200 ppm. The contrast in aluminium saturation index (ASI), and the difference in P, Y and Th abundance between S-type and I-type granites (Chappell, 1999) have been used to distinguish between the two types for strongly crystal fractionated granites.

There are four I-type suites in western Tasmania and King Island; the Housetop (adamellite–alkali-feldspar granite), Renison (adamellite–alkali-feldspar granite), Meredith (mostly adamellite) and Grassy (adamellite); and two S-type suites, the Pieman (adamellite–alkali-feldspar granite) and Interview River (adamellite–alkali-feldspar granite). The S-type Pieman and Interview River and the I-type Housetop and Renison suites have been crystal fractionated. The I-type Meredith and Grassy suites are less differentiated and the Meredith suite shows short linear trends suggesting restite fractionation. The Cox Bight and South West Cape granites in the extreme southwest of Tasmania are probably part of a large subsurface body, based on gravity data, and are poorly known. Their felsic character and associated tin mineralisation suggest that they may be crystal fractionated granite.

In eastern Tasmania the Scottsdale Batholith is entirely I-type and consists of the Diddleum (granodiorite) and Russells Road (tonalite–alkali-feldspar granite) suites. The foliated Diddleum suite bodies intruded before the unfoliated Russells Road suite rocks. Both suites display linear trends on two-element plots, which may have been produced by restite fractionation. The Ben Lomond and Royal George granite (adamellite–alkali-feldspar granite) to the south of the Scottsdale Batholith consists of strongly crystal fractionated and hydrothermally altered S-type and I-type granite.

Further to the east the Blue Tier Batholith and Furneaux Group granites have been divided into six S-type and four I-type suites. The Gardens (mostly granodiorite) is the earliest I-type suite on mainland Tasmania, and like the Wybalenna (granodiorite–adamellite) I-type suite in the Furneaux Group, has a tectonic foliation. Both suites display linear trends on two-element plots and may have been produced by restite fractionation. The Scamander Tier (granodiorite–adamellite) suite is a slightly later unfoliated I-type suite that also displays linear trends on two element plots. This was followed by the Poimena (adamellite–granite) S-type suite which has high Rb values (221–386 ppm) suggesting that it was at least partly crystal fractionated. The last intrusive phase in the central Blue Tier area was the Lottah (mostly alkali-feldspar granite) S-type suite, which has extremely high Rb values (393–1984 ppm) and has undergone extreme crystal fractionation and hydrothermal alteration. The Freycinet (alkali-feldspar granite) I-type suite is strongly crystal fractionated. All other suites, of east and northeast Tasmania and the Furneaux Group; Boobyalla (adamellite–alkali-feldspar granite), Musselroe (adamellite–alkali-feldspar granite), Lady Barron (adamellite) and Babel Island (alkali-feldspar granite); are S-type and mostly show some crystal fractionation.

If the linear variation trends shown by the Diddleum, Russells Road, The Gardens, Scamander Tier and Wybalenna suites were produced by restite fractionation then the source rocks would have been tonalite or granodiorite in composition, matching the most mafic granites on the trends (Chappell, 1984). The source rocks for the Scottsdale Batholith would have had a higher Na_2O/K_2O ratio reflecting a more distinctly I-type character, possibly indicating less contamination from melt derived from a sedimentary source.

The presence of a suite of dolerite dykes in eastern Tasmania, considered to be Devonian in age (McClenaghan, 1984), suggests that there was a large chamber of basic magma in the crust at the time the granites formed. This body of magma might have provided heat for crustal melting and production of the granites. The variation in composition of I-type granites and dolerite dykes in eastern Tasmania suggests that there was mixing of dolerite magma and granitic melt.

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Age and structure of the Arthur Lineament, northwest Tasmania and King Island

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Monazite is a light rare earth element (LREE) phosphate that occurs widely as an accessory mineral, and has been shown to form in sub-greenschist to granulite facies conditions. The abundance of metamorphic monazite increases with progressive metamorphism, and they are being increasingly used to date metamorphic events. Monazites largely reset by recrystallisation and are useful in dating medium to high temperature metamorphic events. CHIME dating (Montel *et al.*, 1996) of monazites enables the dating of small metamorphic grains. The grains can be quickly located, using a back scattered electron detector, and analysed directly in thin section. EMP can analyse small grains, 5–50 μm in diameter. This is a critical feature of the method used here as the monazite grains found in the study were mainly in this size range.

This study included numerous samples from northwest Tasmania and King Island. The aim of this work is to aid the resolution of several contentious aspects of the Mesoproterozoic to Devonian geological history of Tasmania. Whilst these issues have been partly resolved by recent workers (Berry *et al.*, 1997; Black *et al.*, 1997; Turner *et al.*, 1998; Calver, 1998; Calver and Walter, 2000; Meffre *et al.*, 2000), their findings leave many questions unanswered. In particular despite some striking similarities between the depositional and deformational history of the Tasmanian mainland and King Island, the effect of the Wickham Orogeny on northwest Tasmania remains controversial. The effect of the Tyennan Orogeny on King Island is also unknown.

On King Island, CHIME dating gives the age of the Cape Wickham granite as 727 ± 23 Ma, slightly younger than the SHRIMP zircon age (Turner *et al.*, 1998). A schist from the contact aureole has a CHIME age of 759 ± 13 Ma. However samples from southwest King Island, outside the contact aureole, have a CHIME age of 1258 ± 20 Ma (Surprise Bay) and 1224 ± 21 Ma (Fitzmaurice Bay). In both cases these rocks are garnet-bearing schists and the monazites have the HREE depletion typical of monazite growing in equilibrium with garnet (Zhu and O'Nions, 1999). We consider that these CHIME dates uniquely define the age of D_1 on King Island and demonstrate that the regional metamorphism is Grenvillean. The 760 Ma age for the Wickham Orogeny is the age of the local D_2/D_3 events around the granitoids. A sample from the large mylonite zone exposed on the southwest coast of King Island has a few relict old grains (with HREE depletion) but has largely been reset to a Devonian age (381 ± 14 Ma).

The northwest Tasmanian samples have a variety of monazite populations. Schist from the Arthur Lineament shows a well constrained ~510 Ma metamorphic age. Less strained, and perhaps lower grade samples of phyllite and slate from northwest Tasmania have a more complex pattern of monazite age. Despite the restriction of the study to pelites, samples with a detrital component in the age population are common. Monazite grains of 500 Ma are also common, indicating the widespread significance of this event. A few samples show resetting to Devonian ages. There are also a number of grains with CHIME dates between 900–600 Ma. There is no clear peak in these grains at 760 Ma, confirming the absence of any intense Wickham Orogeny in northwest Tasmania. We have not yet been able to demonstrate a difference in diagenetic age between the Rocky Cape Group and the Ahrberg Group.

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Mineral systems – enhanced prospectivity

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The TASGO and TASMAP projects have provided a major impetus to the understanding of the three-dimensional geological architecture of Tasmania and its environs and substantially enhanced temporal constraints on some significant magmatic and tectonic events. It is premature to attempt an analysis of the impact that the substantial body of work will have on the mineral prospectivity of the State, especially as at the time of preparing this abstract I did not have access to most of the detailed results. Nonetheless, preliminary observations of a few examples suggest that the data and techniques used will have lasting importance on the understanding of controls of mineralisation and on the search for new deposits.

The clearest example is provided by the combination of the offshore reflection seismic data, new aeromagnetics, and geological mapping and structural interpretation of northeastern Tasmania that demonstrate a control on orogenic gold deposits in the region by east-dipping thrust faults extending up to 20 km in depth (Barton, 1999; Reed, this volume). The zone includes pervasive faults through the Proterozoic Badger Head block to the west of Beaconsfield and enhances the prospectivity for gold of a 500 km^2 area of outcropping Proterozoic and lower Palaeozoic rocks. Also significant is the clear imaging of the thrust block of probable ultramafic and mafic rocks interpreted to exist at depth west of Bridport, and a possible source rock for gold-bearing fluids (Roach, 1994).

Preliminary lead isotope data show quite disparate ratios between deposits in northeast Tasmania, suggestive of provinciality of source regions for fluids. Data from the Tasmania mine are tightly clustered, indicative of well homogenised fluids from the source region for this major deposit. Galena in minor Zn-Pb mineralisation in the mine, but not in the Tasmania reef, is more radiogenic than the lead in the gold reef and has similar ratios to Devonian granite-related deposits in western Tasmania. There is no geophysical evidence for proximal granite beneath Beaconsfield and it appears likely that the Zn-Pb mineralisation may be younger than the host limestone and introduced either at a different time, or from fluids derived from a different source region, than the gold-forming event. Similarly, several deposits in western Tasmania show strong structural control by, or proximity to, major Devonian faults and no apparent control by granite. Examples are the carbonate-hosted deposits near Zeehan and at Bubs Hill and the bulk of the copper and base metal mineralisation of the Toner River–Balfour trend and at Temma. Understanding the timing and architecture of these smaller systems, from the results of the TASGO and TASMAP projects and from new geophysical data currently being gathered, could well open up new target areas for exploration.

The land-based seismic lines have demonstrated the potential of this technique for resolving the subsurface structures in the Mount Read Volcanics (MRV). A line along the Cradle Mountain Link Road has shown the eastern limit of the Que–Hellyer Volcanics, hidden under Tertiary basalt. The line along the Pieman Road has demonstrated a pattern of thrusting in the Mount Read Volcanics consistent with that shown by the detailed work of Cathryn Gifkins and Rod Allen. The seismic technique seems ideally suited to solving some long-standing unanswered questions of MRV geology, such as the displacement on the Great Lyell Fault in the Mount Lyell mine area and what lies east of the fault at depth.

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