SECTION -C-

A NEW APPROACH TO THE ESTIMATION OF PRESSURE-TEMPERATURE-
DEFORMATION PATHS USING P-T PSEUOSECTIONS COMBINED WITH FIA DATA IN
THE ROBERTSON RIVER METAMORPHICS, NORTHEAST AUSTRALIA
Figure 1. Location map showing major regional geological features and the area in which detailed work done outlined by a box (Compiled from Withnall 1985).
Figure 2. Detailed geological map of the study area outlined in Figure 1 (Modified from Bain et al. 1985). The folded dash lines, which crosscut the area represent the sillimanite (Sill), staurolite-andalusite (St-And) and chlorite-chloritoid (Chl-Cld) isograds.
Figure 3. Photomicrographs showing common textural relationships from the Chl-Cld, St-And and Sill isograd areas a) In the Chl-Cld zone, chloritoid (Cld) porphyroblasts seem to dissolve and leave behind quartz (Qtz) rich pseudomorphs. b) In the St-And zone, chloritoid disappears and garnet porphyroblasts wrapped by staurolite (St) porphyroblasts as inclusion and c) the inclusion trails within garnet porphyroblasts are discontinuous with the matrix unlike staurolite porphyroblasts. d) In addition, andalusite replaces earlier staurolite generations (overgrew S₁) and e) new staurolite generation (overgrew S₁/2) following andalusite replacement is also observed. f) In the Sill zone, all the earlier porphyroblast generations are overprinted by sillimanite plus biotite. S₁-S₄ represents deformation events observed in the matrix. All these photographs are taken from vertical thin sections cut in different orientations around compass as demonstrated in Fig. 4. These orientations are labelled on the lower left corner of the photographs.
A NEW APPROACH TO THE ESTIMATION OF THE P-T-D PATHS

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a)  

b)  

c)
Figure 4. a) Sketches of the oriented rock sample marked and cut into a horizontal slab, and b) multiple-vertical thin sections cut from a horizontal rock slab. FIA is the foliation intersection/inflection axis preserved within porphyroblasts. See appendix for the raw data.
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Table 1. Major element compositions of rock samples (given as weight percent oxide) from the Robertson River Metamorphics in addition to average pelite rock composition of Symmes and Ferry (1991) and a rock sample of Vance and Mahar (1998). The parameters are calculated from mol percent oxides. $A' = \frac{\{Al_2O_3-3K_2O-CaO-Na_2O\}}{\{Al_2O_3-3K_2O-CaO-Na_2O+FeO+MgO\}}$.
Figure 5. a) A structural map shows the distribution of the deformations in the matrix (S₁-S₄). The poles to these structures are plotted on equal area stereonets. b) A cross-section along A-A` shows the relation between macro-scale folds and these matrix deformations.
Figure 6. a) Rose diagrams showing the orientations of total FIA, b) FIA1 (ENE-WSW), FIA2 (E-W) and FIA3 (N-S) in garnet porphyroblasts, and c) FIA2 (E-W), FIA3 (N-S) and FIA4 (NE-SW) in staurolite porphyroblasts across the study area. See Appendix for the FIA data.
Figure 7. Calculated P-T pseudosections for samples mc39 (a), mc55 (b), mc81 (c), mc157 (d). Mineral abbreviations used to indicate fields based on Kretz classification (1983). The small field pointed by (1) refers to a Chl-St-Bt-Plg-Ms-And field. On the pseudosections vertical axis show pressure and horizontal axis temperature.
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Chl Cld Zo Ms
Cld Chl St Plg Ms
Chl Plg Ms
Chl And Plg Ms
Crd Sill Bt Plg Ms
MnNCKFMASH-mc81 Qtz + H2O in excess

450 470 490 510 530 550 570 590 610 630 650 670 690

C10
Figure 8. Compositional maps (Mn, Ca, Fe, Mg) of a garnet porphyroblast from a sample mc152. Light colors show higher and dark colors lower concentration. The stars show the positions of the average of at least three analyses from core and rim.
## A New Approach to the Estimation of the P-T-D Paths

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**A NEW APPROACH TO THE ESTIMATION OF THE P-T-D PATHS**

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| Grossular       | 10.43     | 9.00     | 8.47      | 10.11    | 10.16     | 7.68       | 5.05      |
| Pyrope          | 7.84      | 9.49     | 7.83      | 10.07    | 9.50      | 8.94       | 7.89      |
| Spessartine     | 9.33      | 6.62     | 8.22      | 5.32     | 6.61      | 11.80      | 11.25     |
| Fe/(Fe+Mg)      | 0.90      | 0.89     | 0.91      | 0.88     | 0.89      | 0.89       | 0.91      |

Table 2. Garnet chemistry data from each sample analysed.
Figure 9. Compositional maps (Mn, Ca, Fe, Mg) of a garnet porphyroblast from a sample sample mc39. Light colors show higher and dark colors lower concentration. The stars show the positions of the average of at least three analyses from core, med1, med2 and rim.
### Table 3. Staurolite chemistry data from each sample analysed.

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### A New Approach to the Estimation of the P-T-D Paths

**M. CIHAN**

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**Fe/(Fe+Mg)**

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C16
A NEW APPROACH TO THE ESTIMATION OF THE P-T-D PATHS

M. CIHAN

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### A New Approach to the Estimation of the P-T-D Paths

M. CIHAN

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Table 4. Phyllosilicate chemistry data from each sample analysed.
Figure 10. Compositional maps (Mn, Ca, Fe, Mg) of a garnet porphyroblast from a sample mc55. Light colors show higher and dark colors lower concentration. The stars show the positions of the average of at least three analyses from core, med1, med2 and rim.
A New Approach to the Estimation of the P-T-D Paths

M. CIHAN

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## Table 5. Plagioclase chemistry data from each sample analysed.

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Figure 11. Compositional maps (Mn, Ca, Fe, Mg) of a garnet porphyroblast from a sample mc81. Light colors show higher and dark colors lower concentration. The stars show the positions of the average of at least three analyses from core, med1, med2 and rim.
Figure 12. Compositional maps (Mn, Ca, Fe, Mg) of a garnet porphyroblast from a sample mc157. Light colors show higher and dark colors lower concentration. The stars show the positions of the average of at least three analyses from core, med1, med2 and rim.
Figure 13. The representative pseudosections for samples mc39 (a) and mc81 (b) are to show the distribution of $X_{Mn}$, $X_{Ca}$, $X_{Fe}$ and $X_{An}$ isopleths. Only shaded areas are contoured for clarity. These are Chl-Grt-Plg-\textbf{Bt}-Ms, Chl-Grt-St-Plg-Bt-Ms and Grt-St-Plg-Bt-Ms for sample mc39, and Chl-Grt-Plg-\textbf{St}-Ms, Chl-Grt-St-Plg-Bt-Ms and Grt-St-Plg-Bt-Ms for sample mc81 from left to right respectively.
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Figure 14. The pseudosections showing the P-T estimation of garnet porphyroblast growth by the intersection of three components ($X_{Mn}$, $X_{Ca}$, $X_{Fe}$) for the rock samples mc39 (a), mc55 (b), mc81 (c) and mc157 (d). Grey colours around the individual isopleth lines show their uncertainties, and intersection of these uncertainties point to an uncertainty ellipse of P-T estimation at the time of the core growth. Point analyses from the core of the garnet porphyroblasts within individual rock samples is used for the estimation (See Table 2 and Figs. 8-11).
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a) 7

b) 7

c) 7

d) 7
Figure 15. The pseudosections showing the intersections of $X_{\text{Mn}}$, $X_{\text{Ca}}$, $X_{\text{Fe}}$ and $X_{\text{Car}}$ $X_{\text{An}}$ isopleths from core to median of garnet porphyroblasts within the rock samples mc39 (a), mc55 (b), mc81 (c) and mc157 (d). The data for this is displayed on the pseudosections (See also Figs. 8-11 for the positions of point analyses). The average P-T calculations with their uncertainty ellipses (e) for the rim of garnet porphyroblasts are plotted on the pseudosections for the whole rock samples (see Tables 2 and 6). In addition, uncertainty ellipses of P-T estimations for the core growth of successively formed garnets (See Fig. 14) around FIA1 (ENE-WSW), FIA2 (N-S) and FIA3 (E-W) are also plotted (e); thereby P-T is obtained as shown with dashed arrow line. The white centred circular spots refer to the intersection of $X_{\text{Ca}}$ and $X_{\text{An}}$. The black stripes in uncertainty ellipses indicate the coincidence of likely places for the rim growth on a P-T space.
A NEW APPROACH TO THE ESTIMATION OF THE P-T-D PATHS  
M. CIHAN

\( X_{\text{Mn}}, X_{\text{Ca}}, X_{\text{Fe}}, X_{\text{An}} \)

Core: 0.12 0.17 0.66 NA
med1: 0.08 0.19 0.70 NA
med2: ~ 0.04 0.16 0.73 NA

Core: 0.16 0.15 0.64 NA
med1: 0.11 0.16 0.67 NA
med2: 0.07 0.15 0.72 NA

Core: 0.15 0.13 0.65 NA
med1: 0.12 0.13 0.68 NA
med2: 0.09 0.12 0.72 0.40

Core: 0.18 0.12 0.64 0.42
med1: 0.10 0.12 0.71 0.36
med2: 0.06 0.10 0.75 NA

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M. CIHAN

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mineral phases</th>
<th>T(°C)</th>
<th>Error</th>
<th>P(kb)</th>
<th>Error</th>
<th>Correlation Fit</th>
<th>Sigfit</th>
<th>95% confid. fit</th>
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</thead>
<tbody>
<tr>
<td>mc39</td>
<td>Grt+St+Bt+Ms</td>
<td>610</td>
<td>80</td>
<td>6.8</td>
<td>2.9</td>
<td>-0.513</td>
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<td>25</td>
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<td>0.812</td>
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<td>51</td>
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<td>0.576</td>
<td>1.09</td>
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<tr>
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<td>24</td>
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<td>1.0</td>
<td>0.786</td>
<td>0.81</td>
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<tr>
<td>mc157</td>
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<td>46</td>
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<td>0.575</td>
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<td>0.6</td>
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<tr>
<td>mc158</td>
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<td>596</td>
<td>32</td>
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<td>0.803</td>
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<td>1.16</td>
<td>1.61</td>
</tr>
</tbody>
</table>

Table 6. Average P-T calculations. Correlation fit is a measure of how correlated the pressure and temperature on a scale from ±1-0. 0 = uncorrelated, ±1 = completely correlated. Sigfit is the result of a Chi-squared test at 95% confidence. If it is less than the number presented in the 95% confid fit column, all the calculated equilibrium overlap the P-T estimate within 95% confidence level.
Figure 16. Derivation of complete P-T path based on the methods explained in the text. O₁-O₄ describes the four periods of shortening events accompanied or followed by three metamorphic events, M₁-M₃.