

# LA ICP-MS trace element and oxygen isotope variation of vanadium-rich ruby and sapphire within Mogok Gemfield, Myanmar

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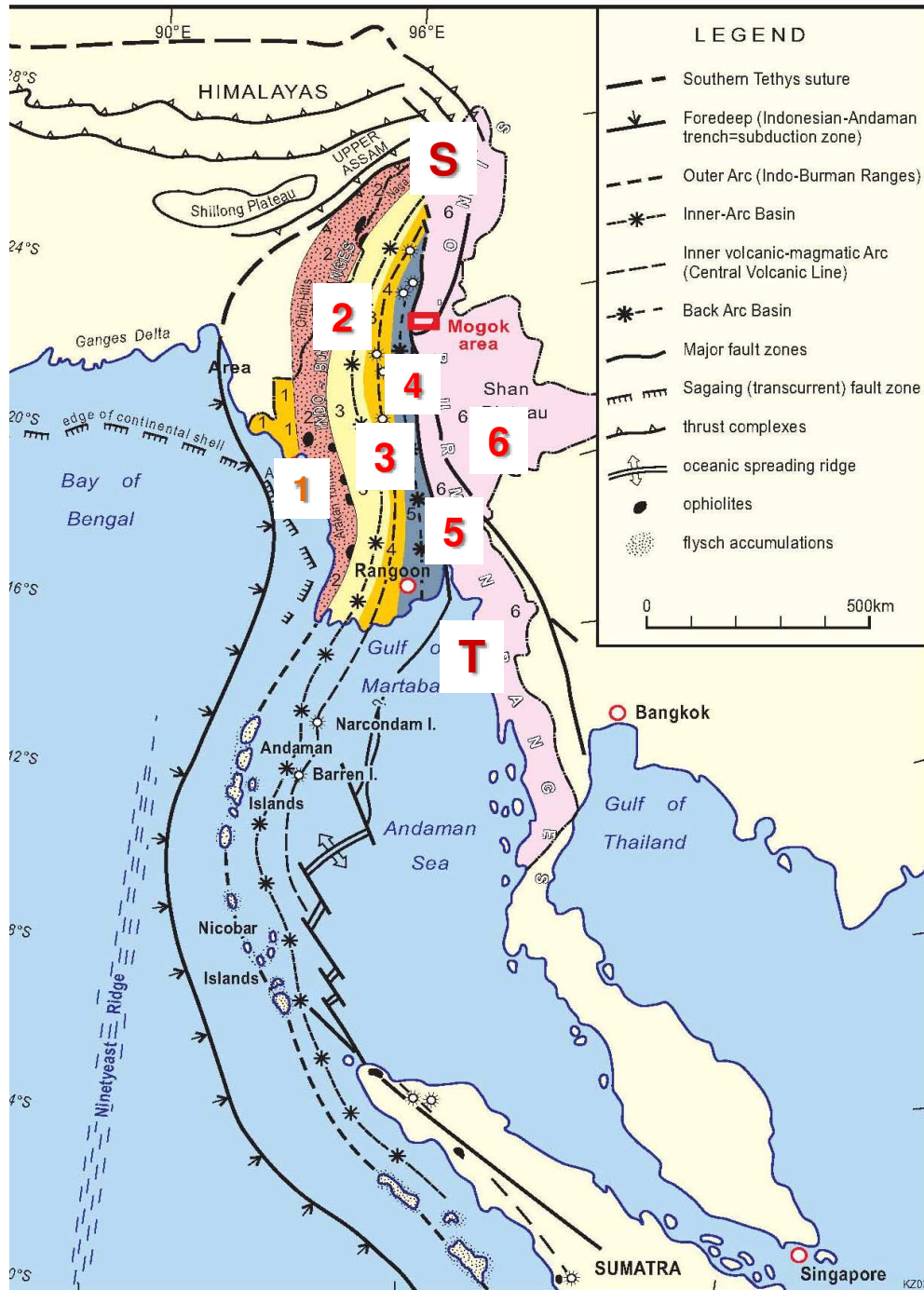
# Outline of Talk

- **Regional and Local Geological setting**
- **LA ICP-MS Trace Elements and imaging**

- **Oxygen Isotopes**



- **Implications for Colour and origin**

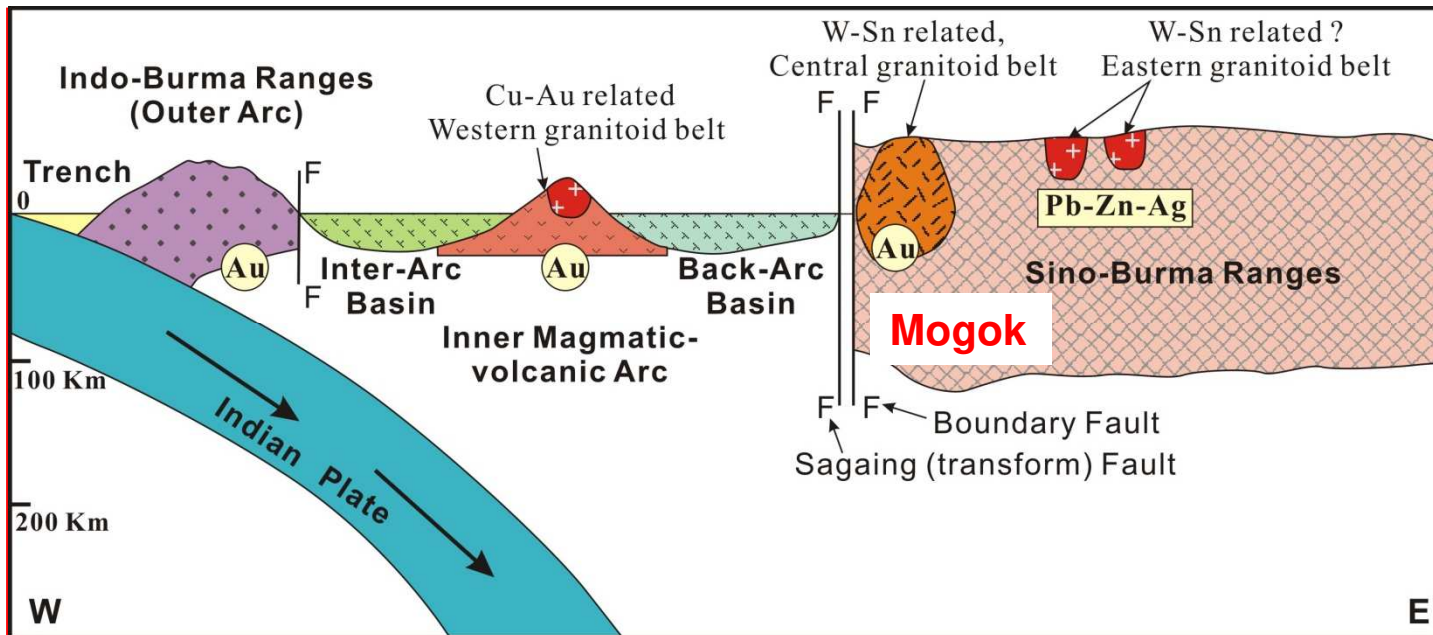


**Myanmar can be sub-divided into six N-S trending tectonic domains:**

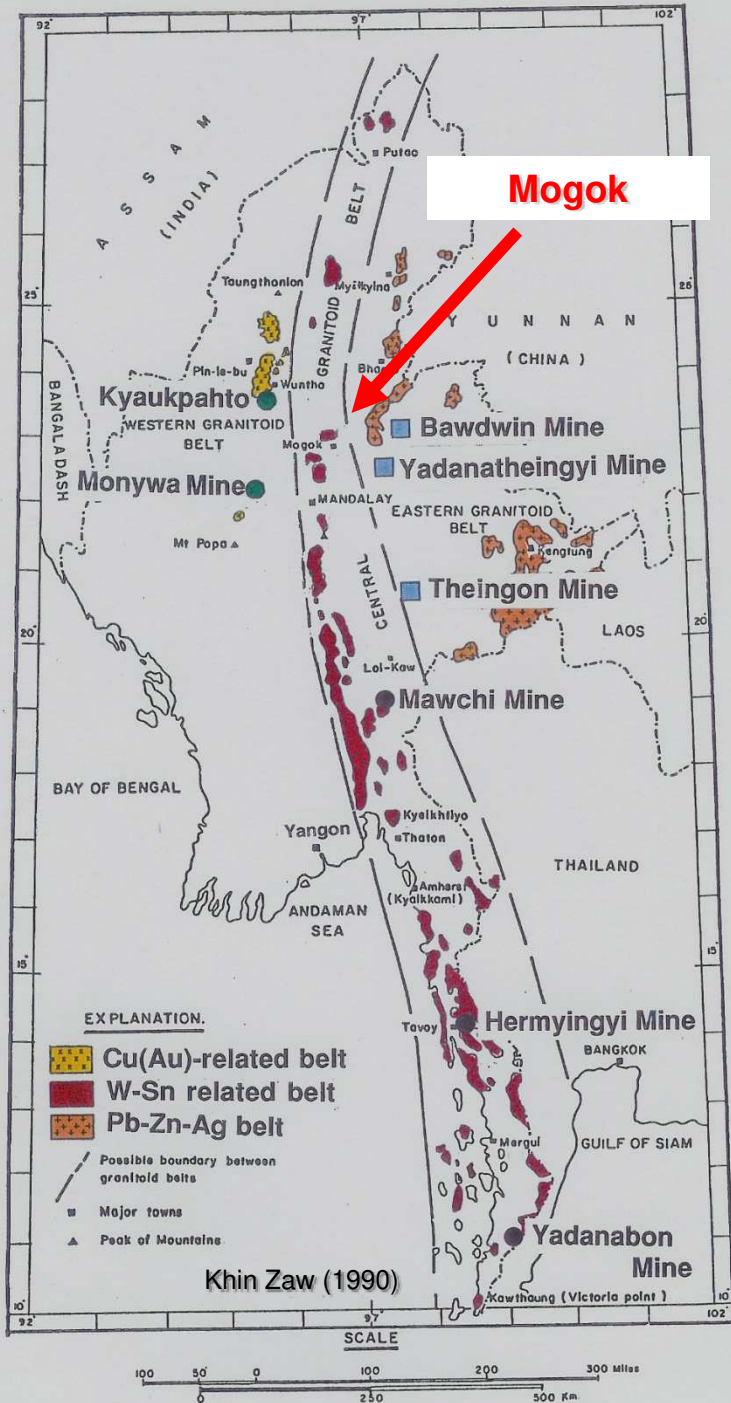
- (1) Arakan (Rakhine) Coastal strip**
- (2) Indo-Burman Ranges (Fore Arc)**
- (3) Inter-arc basin**
- (4) Inner magmatic-volcanic arc**
- (5) Back-arc basin and**
- (6) Sino-Myanmar Ranges**

**The Sagaing Transform (S-T) (transfer) fault as a tectonic boundary between older Sino-Myanmar Ranges and younger belts to the west.**

After Bender (1983); Khin Zaw (1989, 1990)



| Tectonic belt               | Rock Type  | Mineral potential  |
|-----------------------------|--|--|
| Indo-Burman Ranges          | Triassic-Cretaceous-Eocene flysch with ophiolite             | Cr, Ni, PGE, Cyprus type Cu(Au)?                               |
| Inner magmatic-volcanic arc | Late Cretaceous-Tertiary calc-alkaline to alkaline volcanics | Epithermal Cu(Au), Au-Ag, sediment-hosted Au                   |
| Sino-Burman Ranges          | Cambrian to Palaeozoic sediments & Mesozoic clastics         | Base metals, W-Sn, Ruby, Sapphire, Jade, Diamond & Orogenic Au |

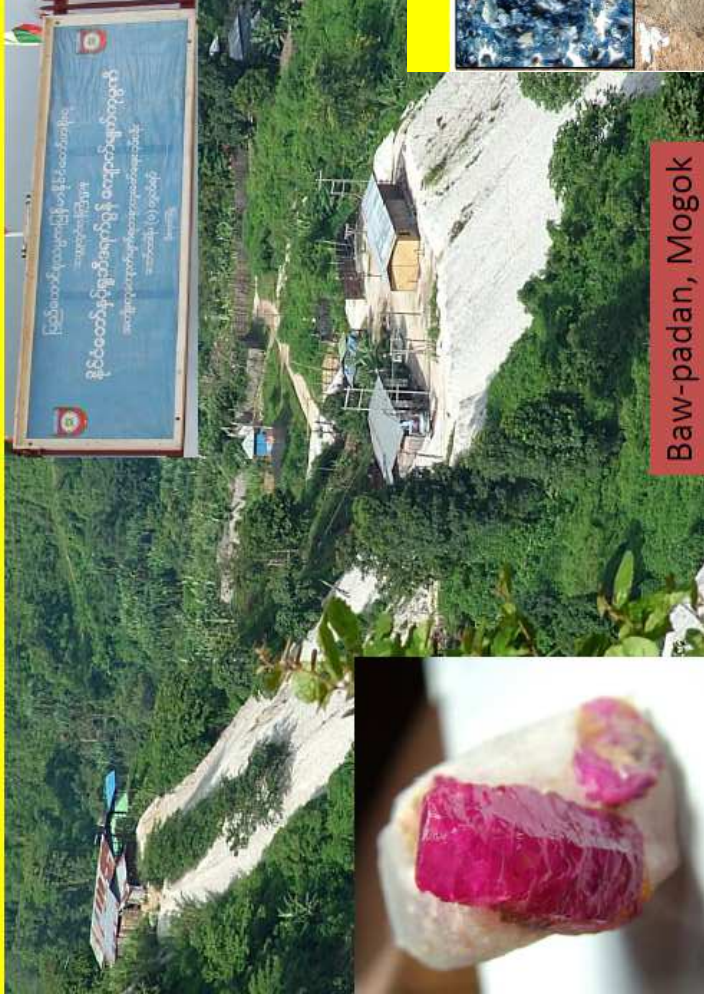



**Annual Meeting**  
**Asia Oceania Geosciences Society**  
 24 to 28 June, 2013  
**Brisbane**

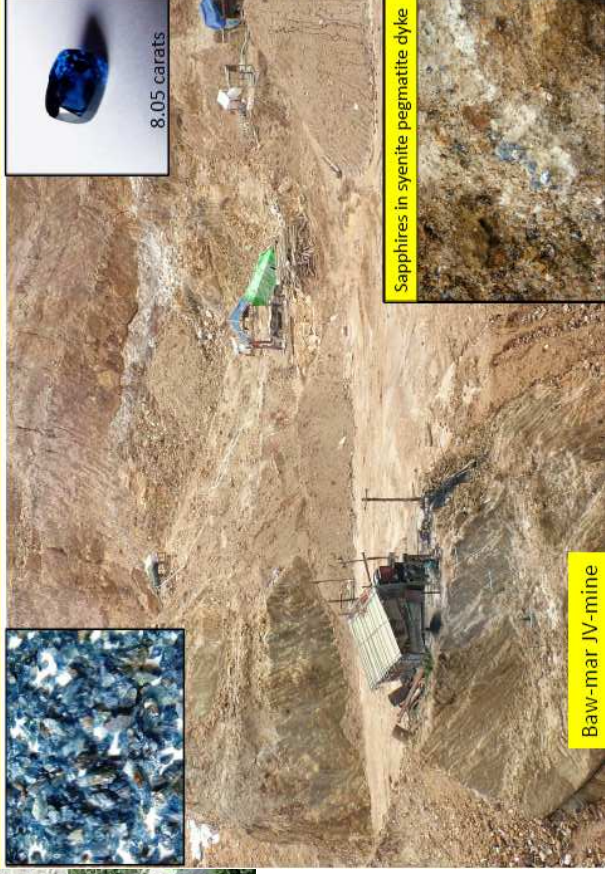


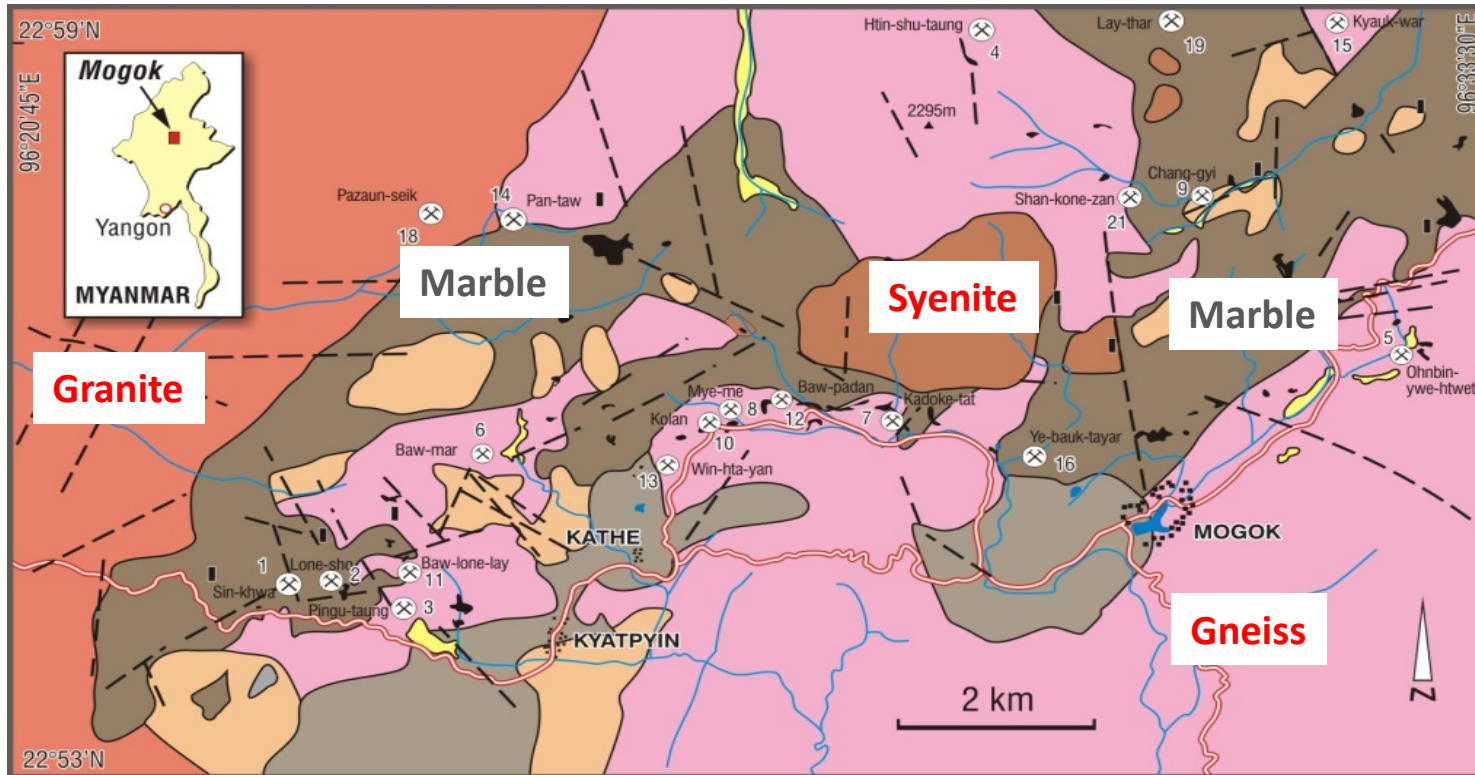


# 1. RUBY IN MARBLE



# SAPPHIRE IN SYENITE PEGMATITE





- Alluvium
- Leucogranite
- Biotite microgranite (Kabaing Granite)
- Syenitic rocks

**LEGEND**

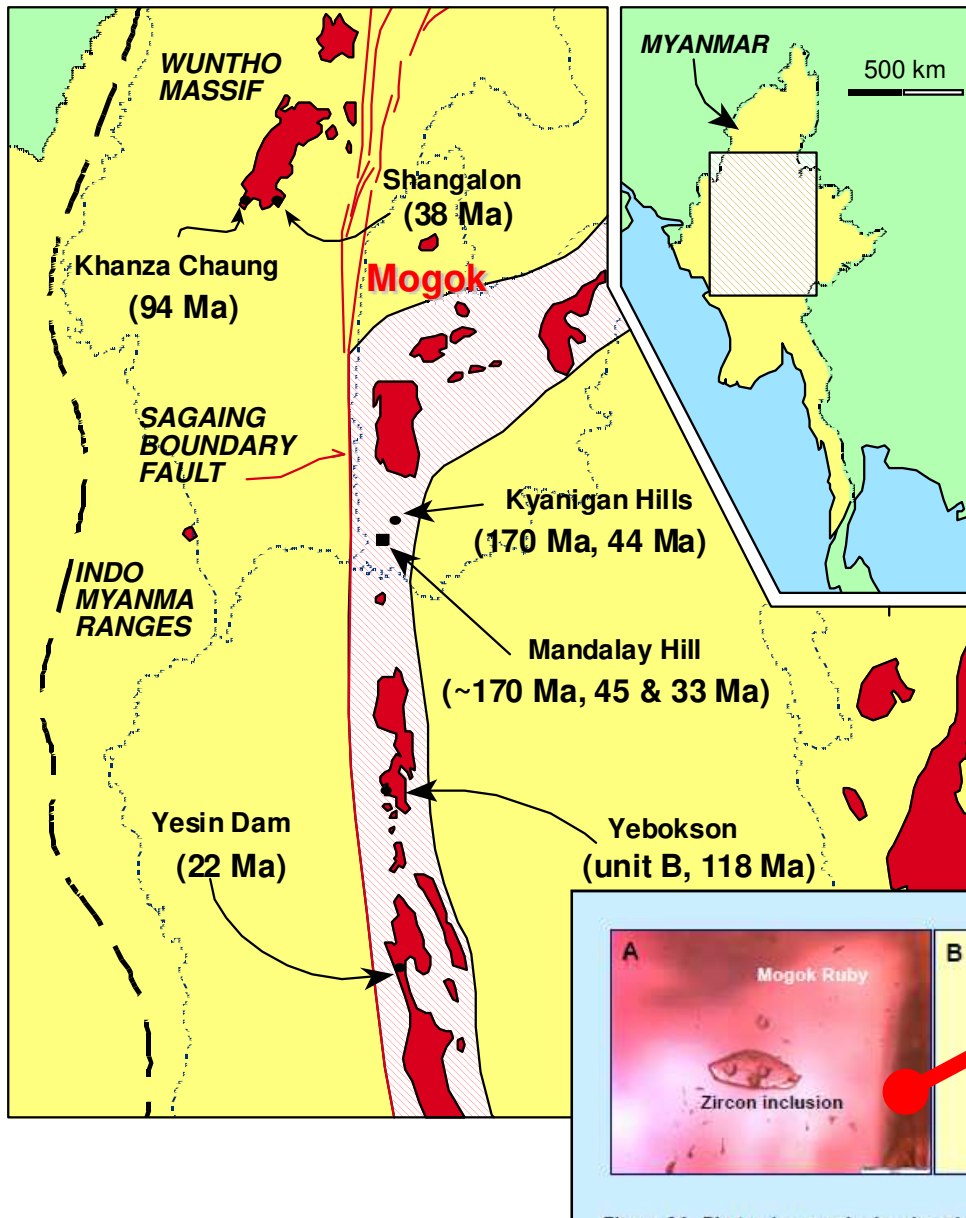
- Quartzite
- Marble (M1); Ruby-bearing marble
- Marble (M2); Graphite marble
- Gneiss

- Fault
- Gem-bearing skarn
- Gem mine/working
- ⊗ Gem mine/working studied
- Village/Town
- Roads
- Stream
- Peak (in metres)

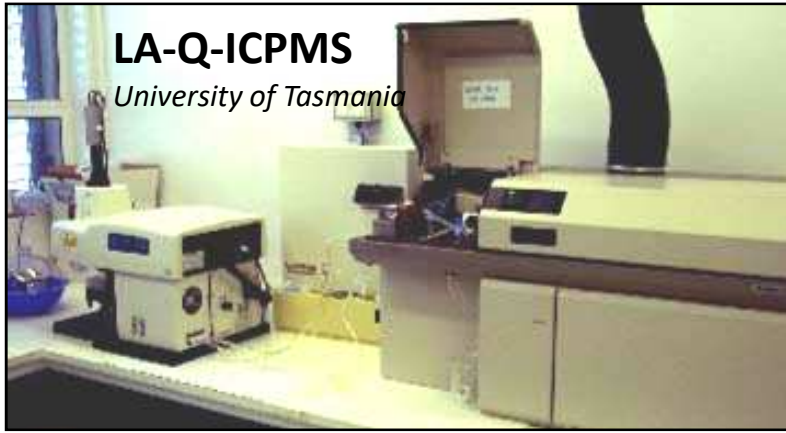




# Multiple ages of Mogok Belt



- SHRIMP zircon: **Jurassic through Cretaceous** to Miocene (Barley et al. 2003)
- Ar–Ar biotite age of 15.8 Ma granitoid and Ar–Ar biotite for metamorphic rocks: 16.5 to 19.5 Ma (Bertrand et al. 2001) (**Miocene**)
- Ar–Ar phlogopite ages for a ruby-bearing marble of 18.7 Ma and ruby-free marbles of 17.1 and 17.9 Ma (Garnier et al. 2006) (**Miocene**)
- LA ICP-MS leucocratic granite intrusions at Mogok: 45 and 25 Ma (Kyaw Thu, 2007). (**Eocene-Oligocene**)
- U–Pb dating of zircon inclusions in a Mogok ruby gave 31 to 32 Ma age (Khin Zaw et al. 2008, 2010) (**Oligocene**)



**LA-Q-ICPMS**  
University of Tasmania



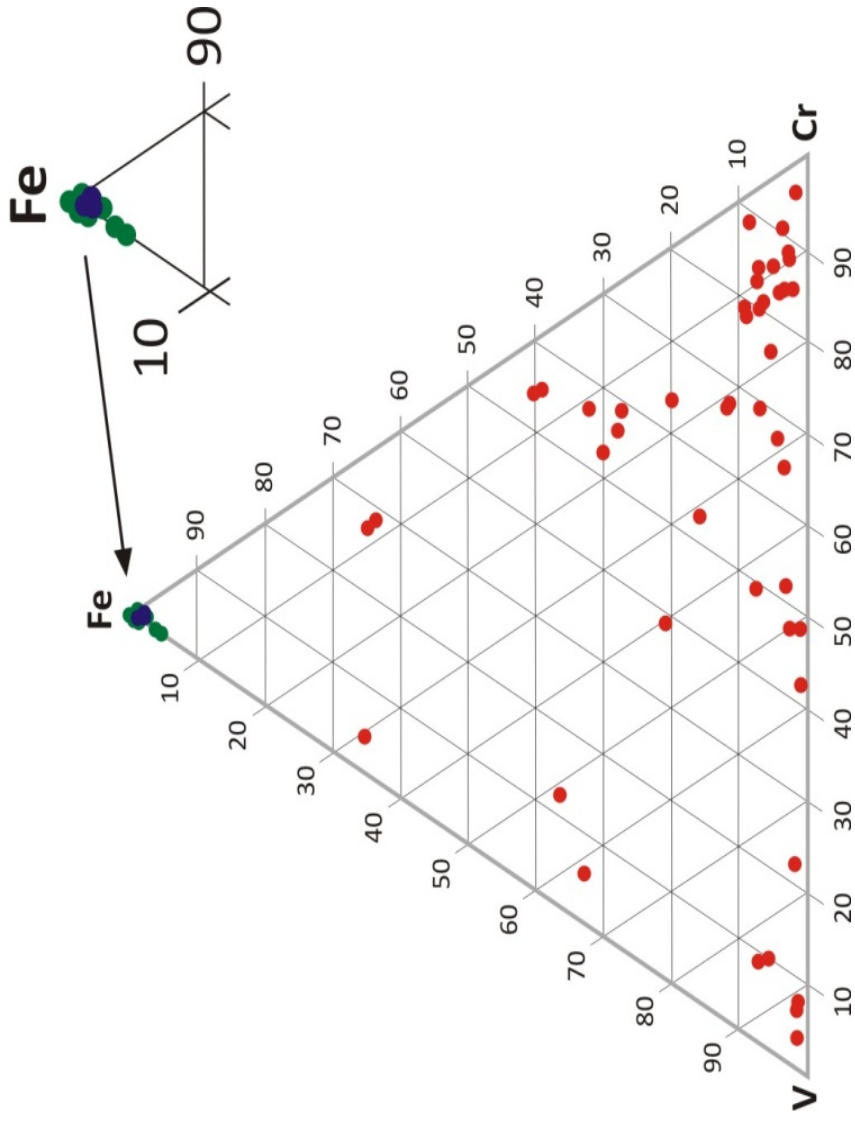
laser



Mass spectrometer

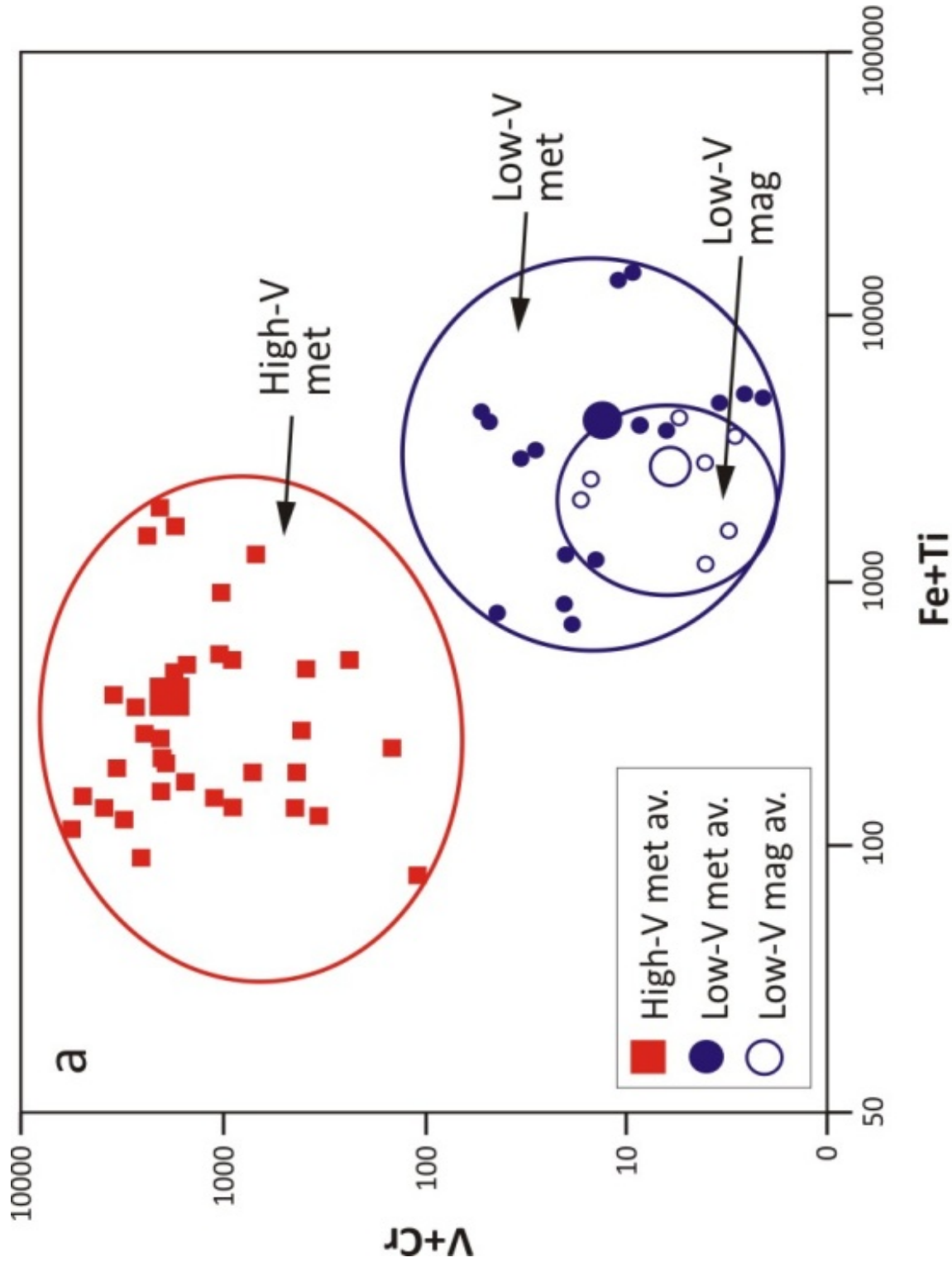


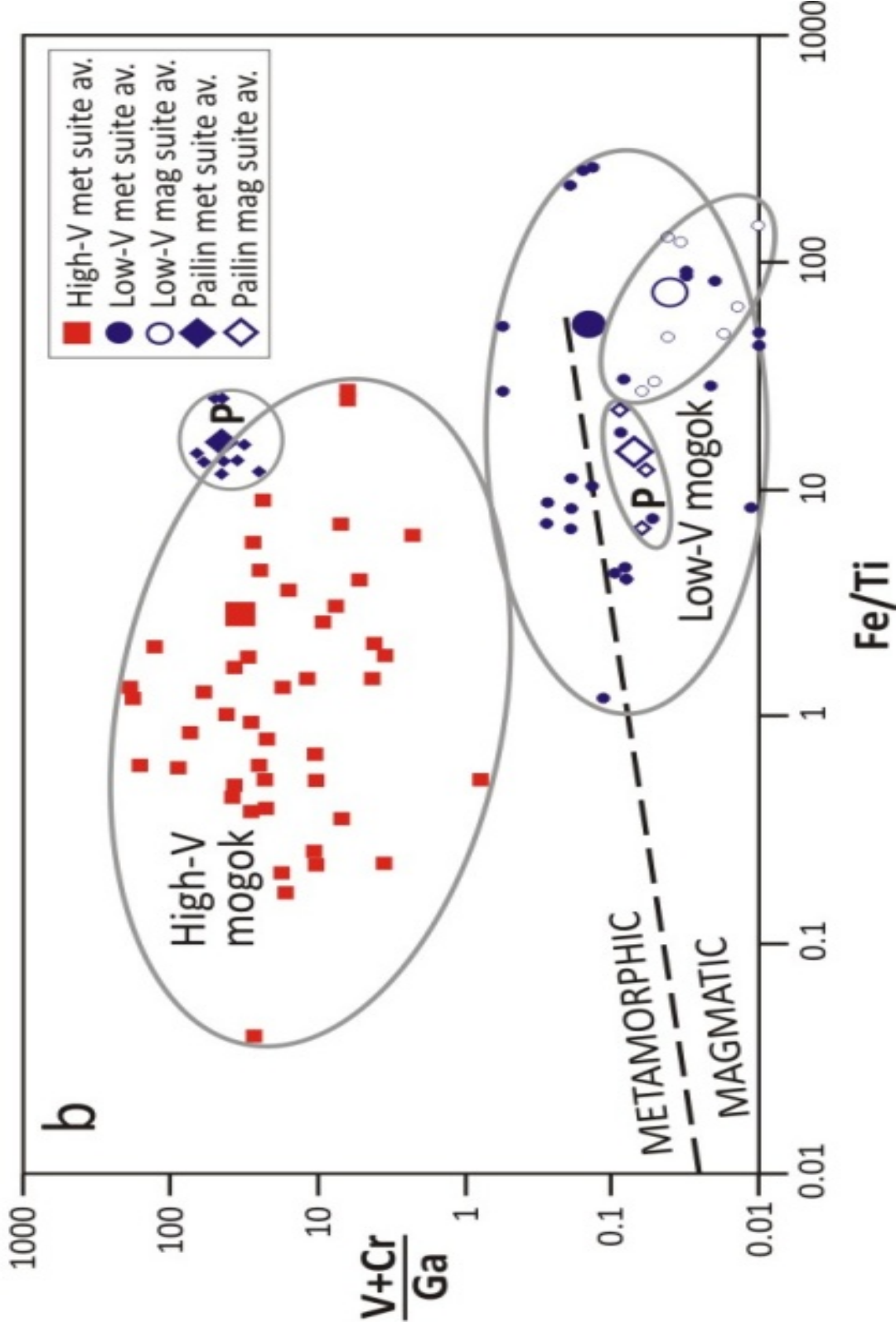
| Sample Site                                   | Colour      | Latitude    | Longitude   | No. | V         | Cr         | Fe             | Ti          | Mg         | Ga        | V/Cr        | V+Cr/Ga         |                 |
|---|-------------|-------------|-------------|-----|-----------|------------|----------------|-------------|------------|-----------|-------------|-----------------|-----------------|
| <i>High V (&gt;90ppm) Metamorphic suites</i>  |             |             |             |     |           |            |                |             |            |           |             |                 |                 |
| Sin-khwa (1)*                                 | red         | 22°54'31"   | 96°23'10"   | 1.r | 5044      | 369        | 76             | 56          | 39         | 27        | 13.67       | 200.48          |                 |
|   |             |             |             | 1.c | 5213      | 433        | 67             | 54          | 34         | 31        | 12.04       | 182.13          |                 |
| Sin-khwa (1)*                                 | red         | 22°54'31"   | 96°23'10"   | 2.r | 3960      | 3758       | 79             | 132         | 105        | 90.1      | 1.05        | 85.66           |                 |
|   |             |             |             | 2.c | 4271      | 165        | 59             | 95          | 31         | 27.6      | 25.89       | 160.72          |                 |
| Lone-sho (2)*                                 | red         | 22°54'34"   | 96°23'30"   | 1.r | 2970      | 867        | 65             | 76          | 60         | 52.4      | 3.43        | 73.23           |                 |
|   |             |             |             | 1.c | 101       | 9          | 54             | 26          | 36         | 27.2      | 11.22       | 4.04            |                 |
| Pingu-taung (3)**                             | red-purple  | 22°54'19"   | 96°24'05"   | 1.r | 906       | 1039       | 59             | 95          | 30         | 75.8      | 0.87        | 25.66           |                 |
|   |             |             |             | 1.c | 1297      | 1229       | 57             | 34          | 27         | 69        | 1.06        | 36.61           |                 |
| Pingu-taung (3)**                             | purple      | 22°54'19"   | 96°24'05"   | 2.r | 456       | 2896       | 67             | 134         | 72         | 92.3      | 0.16        | 36.32           |                 |
|   |             |             |             | 2.c | 575       | 1154       | 58             | 1580        | 68         | 64.7      | 0.5         | 26.72           |                 |
| Htin-shu-taung (4)*                           | purple      | 23°00'23.5" | 96°28'40"   | 1.r | 153       | 521        | 1228           | 50          | 15         | 107.8     | 0.29        | 6.25            |                 |
|   |             |             |             | 1.c | 148       | 549        | 1232           | 46          | 11         | 109.9     | 0.27        | 6.34            |                 |
| Htin-shu-taung (4)*                           | dark purple | 23°00'23.5" | 96°28'40"   | 2.r | 465       | 1951       | 901            | 150         | 57         | 89.4      | 0.24        | 26.92           |                 |
|   |             |             |             | 2.c | 341       | 1691       | 955            | 105         | 66         | 84.6      | 0.2         | 24.02           |                 |
| Ohnbin-ywe-htwet (5)*                         | light pink  | 22°56'32"   | 96°32'10"   | 1.r | 119       | 1071       | 28             | 106         | 61         | 112.7     | 0.11        | 10.56           |                 |
|   |             |             |             | 1.c | 104       | 1005       | 27             | 117         | 81         | 106.3     | 0.11        | 10.43           |                 |
| Ohnbin-ywe-htwet (5)*                         | light pink  | 22°56'32"   | 96°32'10"   | 2.r | 181       | 524        | 51             | 140         | 88         | 102.4     | 0.35        | 6.88            |                 |
|   |             |             |             | 2.c | 174       | 714        | 49             | 92          | 78         | 87.5      | 0.24        | 10.15           |                 |
| Baw-mar (6)*                                  | pink        | 22°55'39.9" | 96°24'43"   | 1.r | 96        | 908        | 671            | 248         | 144        | 107.4     | 0.11        | 9.35            |                 |
|   |             |             |             | 1.c | 98        | 928        | 655            | 246         | 135        | 109.5     | 0.11        | 9.37            |                 |
| Baw-mar (6)*                                  | red         | 22°55'39.9" | 96°24'43"   | 1.r | 186       | 1560       | 131            | 335         | 215        | 64.5      | 0.12        | 27.07           |                 |
|   |             |             |             | 1.c | 206       | 1250       | 138            | 348         | 260        | 66.9      | 0.17        | 21.76           |                 |
| Kadoke-tat (7)**                              | pink        | 22°56'02"   | 96°28'01"   | 1.r | 171       | 165        | 88             | 47          | 25         | 94.7      | 1.04        | 3.55            |                 |
|   |             |             |             | 1.c | 163       | 277        | 83             | 57          | 35         | 104       | 0.59        | 4.23            |                 |
| Mye-me (8)*                                   | red         | 22°56'02"   | 96°26'42"   | 1.r | 520       | 1221       | 77             | 95          | 54         | 78.7      | 0.43        | 22.12           |                 |
|   |             |             |             | 1.c | 483       | 356        | 60             | 88          | 50         | 80.7      | 1.36        | 10.4            |                 |
| Mye-me (8)*                                   | purple-pink | 22°56'02"   | 96°26'42"   | 2.r | 1555      | 185        | 102            | 100         | 53         | 41        | 8.41        | 42.44           |                 |
|   |             |             |             | 2.c | 1430      | 154        | 120            | 59          | 32         | 12.3      | 9.29        | 128.8           |                 |
| Chaug-gyi (9)*                                | red         | 22°57'51"   | 96°30'32"   | 1.r | 92        | 353        | 110            | 85          | 48         | 7.5       | 0.26        | 59.33           |                 |
|   |             |             |             | 1.c | 99        | 313        | <52            | 224         | 57         | 7.7       | 0.32        | 3.51            |                 |
| Chaug-gyi (9)*                                | red         | 22°57'51"   | 96°30'32"   | 2.r | 117       | 28         | 83             | 157         | 23         | 179       | 4.18        | 0.81            |                 |
|   |             |             |             | 2.c | 228       | 712        | 123            | 31          | 15         | 185       | 0.32        | 5.08            |                 |
| Kolan (10)**                                  | red         | 22°55'55"   | 96°26'33"   | 2.r | 226       | 802        | 396            | 143         | 69         | 148       | 0.28        | 6.94            |                 |
|   |             |             |             | 2.c | 223       | 683        | 388            | 125         | 61         | 155       | 0.32        | 7.78            |                 |
| Baw-lone-lay (11)**                           | red         | 22°54'38"   | 96°24'07"   | 1.r | 257       | 1671       | 129            | 87          | 45         | 164       | 0.15        | 11.76           |                 |
|   |             |             |             | 1.c | 191       | 1871       | 148            | 109         | 52         | 119       | 0.1         | 17.33           |                 |
| Baw-lone-lay (11)**                           | red         | 22°54'38"   | 96°24'07"   | 2.r | 201       | 1810       | 100            | 103         | 53         | 69.9      | 0.11        | 28.77           |                 |
|   |             |             |             | 2.c | 124       | 1867       | 67             | 152         | 69         | 54.8      | 0.07        | 36.33           |                 |
| Baw-padan (12)**                              | red         | 22°56'09"   | 96°27'05"   | 1.r | 206       | 29         | 442            | 70          | 33         | 106       | 7.1         | 2.22            |                 |
|   |             |             |             | 1.c | 347       | 2339       | 270            | 74          | 40         | 166       | 0.15        | 16.18           |                 |
| Baw-padan (12)**                              | red         | 22°56'09"   | 96°27'05"   | 2.r | 109       | 3359       | 310            | 69          | 35         | 142       | 0.03        | 24.42           |                 |
|   |             |             |             | 2.c | 96        | 3003       | <45            | 84          | 40         | 131       | 0.03        | 22.92           |                 |
| Win-hta-yan (13)**                            | red-purple  | 22°55'34"   | 96°26'12"   | 1.r | 202       | 1327       | <61            | 292         | 156        | 89.8      | 0.15        | 17.03           |                 |
|   |             |             |             | 1.c | 193       | 1254       | <47            | 279         | 157        | 88.7      | 0.15        | 16.31           |                 |
| Win-hta-yan (13)**                            | red-purple  | 22°55'34"   | 96°26'12"   | 2.r | 340       | 2081       | 173            | 93          | 52         | 80.2      | 0.16        | 30.19           |                 |
|   |             |             |             | 2.c | 261       | 297        | <45            | 7639        | 63         | 60.4      | 0.88        | 9.24            |                 |
| <b>Average 13 sites</b>                       |             |             |             |     | <b>46</b> | <b>759</b> | <b>1103</b>    | <b>224</b>  | <b>153</b> | <b>66</b> | <b>88.5</b> | <b>2.35</b>     | <b>33.21</b>    |
| <i>Low V (&lt; 35ppm) intermediate suites</i> |             |             |             |     |           |            |                |             |            |           |             |                 |                 |
| Lone-sho (2)*                                 | blue        | 22°54'34"   | 96°23'30"   | 2.r | 3         | <1.1       | 679            | 90          | 59         | 77.8      | >2.54       | 0.05            |                 |
|   |             |             |             | 2.c | 5         | <1.0       | 849            | 209         | 133        | 75.5      | >4.48       | 0.08            |                 |
| Pan-taw (14)*                                 | light blue  | 22°57'36.7" | 96°24'58.9" | 1.r | 7         | 1          | 609            | 138         | 71         | 93.6      | 5.34        | 0.09            |                 |
|   |             |             |             | 1.c | 7         | 1          | 656            | 150         | 86         | 96.3      | 6.64        | 0.08            |                 |
| Kyauk-war (15)*                               | blue        | 22°59'02"   | 96°32'30"   | 1.r | 1         | 1          | 4913           | 57          | 27         | 69.9      | 0.56        | 0.03            |                 |
|   |             |             |             | 1.c | 1         | <1.2       | 5117           | 58          | 24         | 71.5      | >0.48       | 0.03            |                 |
| Kyauk-war (15)*                               | blue        | 22°59'02"   | 96°32'30"   | 2.r | 5         | <0.8       | 3717           | 124         | 67         | 74.2      | >4.67       | 0.08            |                 |
|   |             |             |             | 2.c | 7         | <1.1       | 3853           | 207         | 122        | 96.7      | >6.24       | 0.08            |                 |
| Ye-bauk-tayar (16)*                           | light blue  | 22°55'40"   | 96°29'10"   | 2.r | 29        | 1          | 2708           | 375         | 167        | 116.3     | 20.28       | 0.26            |                 |
|   |             |             |             | 2.c | 32        | <1.1       | 2633           | 297         | 179        | 116.3     | 27.83       | 0.28            |                 |
| Chang-gyi (9)*                                | blue        | 22°57'51"   | 96°30'32"   | 1.r | 6         | 14         | 1165           | 104         | 65         | 103.7     | 0.4         | 0.19            |                 |
|   |             |             |             | 1.c | 5         | 9          | 1126           | 111         | 57         | 102       | 0.56        | 0.14            |                 |
| Chang-gyi (9)*                                | light blue  | 22°57'51"   | 96°30'32"   | 1.r | 18        | <1.0       | 646            | 78          | 50         | 105.5     | >18.0       | 0.18            |                 |
|   |             |             |             | 1.c | 18        | <0.9       | 607            | 89          | 54         | 105.4     | >20.2       | 0.18            |                 |
| Le-shu-kone-zan (17)*                         | dark blue   | 22°58'30"   | 96°39'50"   | 2.r | 18        | 30         | 3928           | 147         | 83         | 89.3      | 0.6         | 0.53            |                 |
|   |             |             |             | 2.c | 18        | 33         | 4346           | 81          | 43         | 90.8      | 0.55        | 0.56            |                 |
| Pazaun-seik (18)*                             | dark blue   | 22°57'43.3" | 96°24'15.6" | 1.r | 9         | 0.5        | 14779          | 56          | 10         | 66.3      | 18          | 0.14            |                 |
|   |             |             |             | 1.c | 10        | 0.6        | 14485          | 56          | 10         | 67.4      | 16.7        | 0.16            |                 |
| Pazaun-seik (18)*                             | dark blue   | 22°57'43.3" | 96°24'15.6" | 2.r | 10        | 0.7        | 14283          | 63          | 11         | 55.4      | 14.3        | 0.19            |                 |
|   |             |             |             | 2.c | 19        | 1.3        | 498            | 331         | 103        | 190       | 14.6        | 0.11            |                 |
| Lay-thar (19)*                                | medium blue | 23°00'26.3" | 96°30'19.5" | 1.r | 3         | <0.6       | 4804           | 52          | 27         | 125       | >5.0        | <0.03           |                 |
|   |             |             |             | 1.c | 3         | <0.6       | 4682           | 57          | 28         | 136       | >5.0        | <0.02           |                 |
| Lay-thar (19)*                                | pale blue   | 23°00'26.3" | 96°30'19.5" | 2.r | 1         | 1          | 2665           | 63          | 107        | 135       | 1           | 0.01            |                 |
|   |             |             |             | 2.c | 1         | 1          | 2716           | 331         | 119        | 135       | 1           | 0.01            |                 |
| <b>Average 8 sites</b>                        |             |             |             |     | <b>24</b> | <b>8</b>   | <b>&lt;4.2</b> | <b>3933</b> | <b>139</b> | <b>63</b> | <b>96.4</b> | <b>&gt;7.76</b> | <b>&lt;0.14</b> |
| <i>Low V (&lt; 10ppm) magmatic suites</i>     |             |             |             |     |           |            |                |             |            |           |             |                 |                 |
| Ye-bauk-tayar (16)*                           | blue        | 22°55'40"   | 96°29'10"   | 1.r | 3         | <1.1       | 1171           | 24          | 23         | 230.5     | >2.51       | 0.018           |                 |
|   |             |             |             | 1.c | 2         | <1.1       | 1557           | 24          | 19         | 223.3     | >2.16       | 0.014           |                 |
| Shan-kone-zan (20)*                           | blue        | 22°57'52"   | 96°29'56"   | 1.r | 4         | <1.09      | 2705           | 54          | 22         | 109.9     | >4.25       | 0.046           |                 |
|   |             |             |             | 1.c | 4         | <1.08      | 2732           | 55          | 23         | 109.4     | >4.80       | 0.046           |                 |
| Shan-kone-zan (20)*                           | blue        | 22°57'52"   | 96°29'56"   | 1.r | 4         | <1.0       | 3927           | 29          | 40         | 110.2     | >3.88       | 0.045           |                 |
|   |             |             |             | 1.c | 3         | <1.1       | 3808           | 30          | 38         | 111.9     | >2.90       | 0.037           |                 |
| Le-shu-kone-zan (17)*                         | dark blue   | 22°58'30"   | 96°39'50"   | 2.r | 9         | 6          | 2420           | 81          | 8          | 284       | 1.5         | 0.05            |                 |
|   |             |             |             | 2.c | 9         | 8          | 1952           | 71          | 19         | 286       | 1.13        | 0.06            |                 |
| <b>Average 4 sites</b>                        |             |             |             |     | <b>8</b>  | <b>4</b>   | <b>&lt;2.2</b> | <b>2689</b> | <b>44</b>  | <b>22</b> | <b>171</b>  | <b>&gt;1.82</b> | <b>&lt;0.04</b> |
| r = rim, c = core * = Placer, ** = Primary    |             |             |             |     |           |            |                |             |            |           |             |                 |                 |

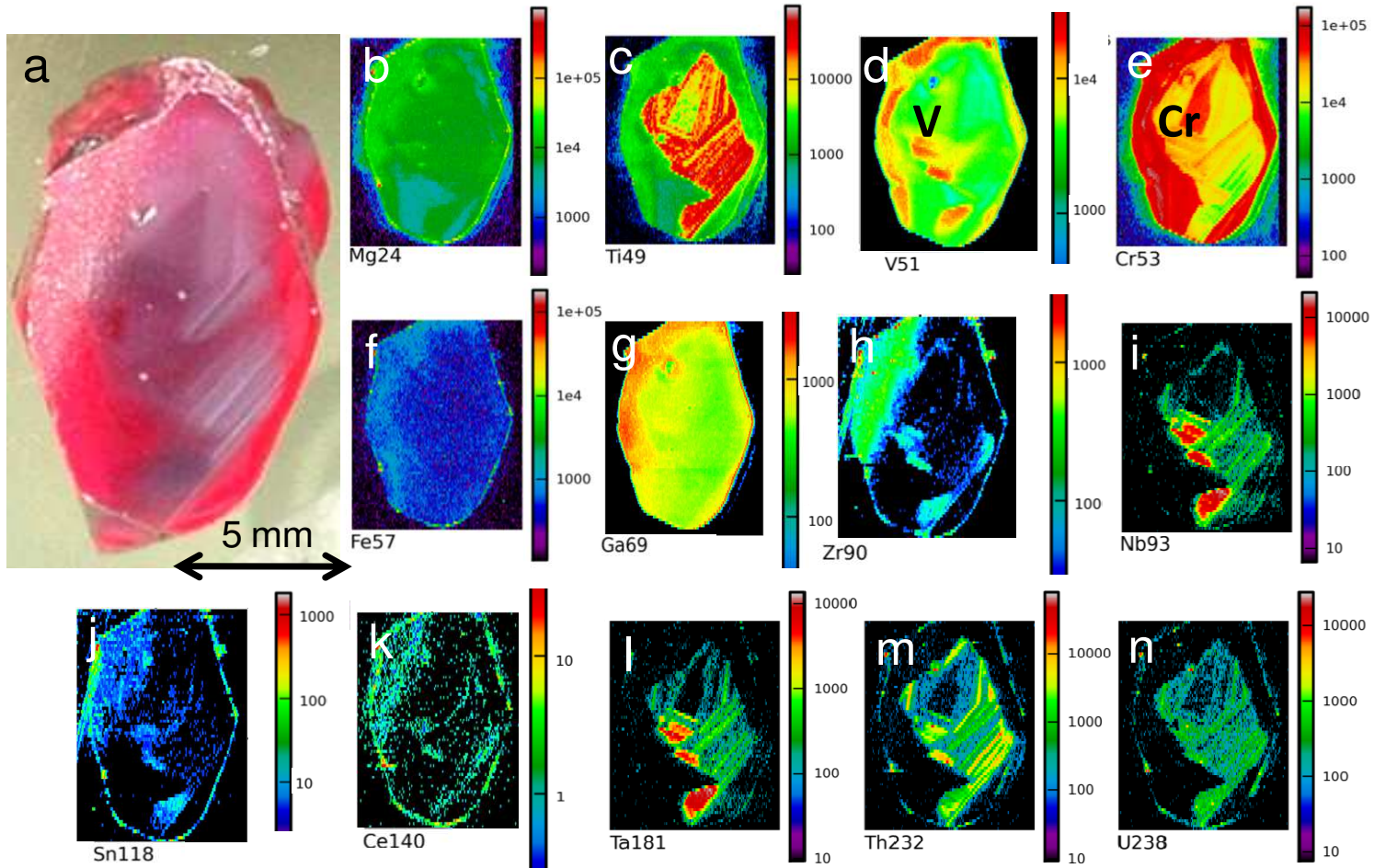


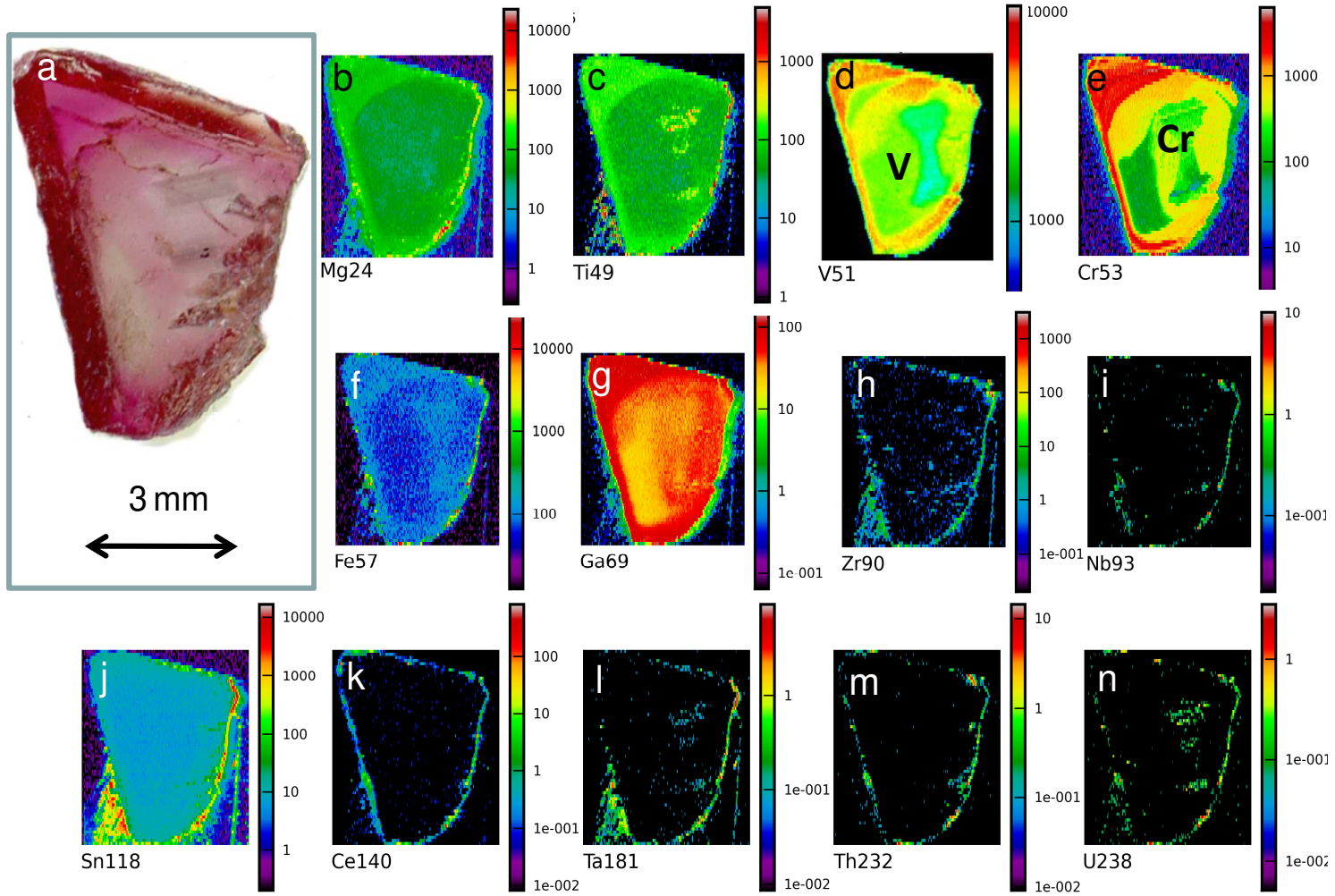

 Annual Meeting  
**Asia Oceania Geosciences Society**  
 24 to 28 June, 2013  
**Brisbane**





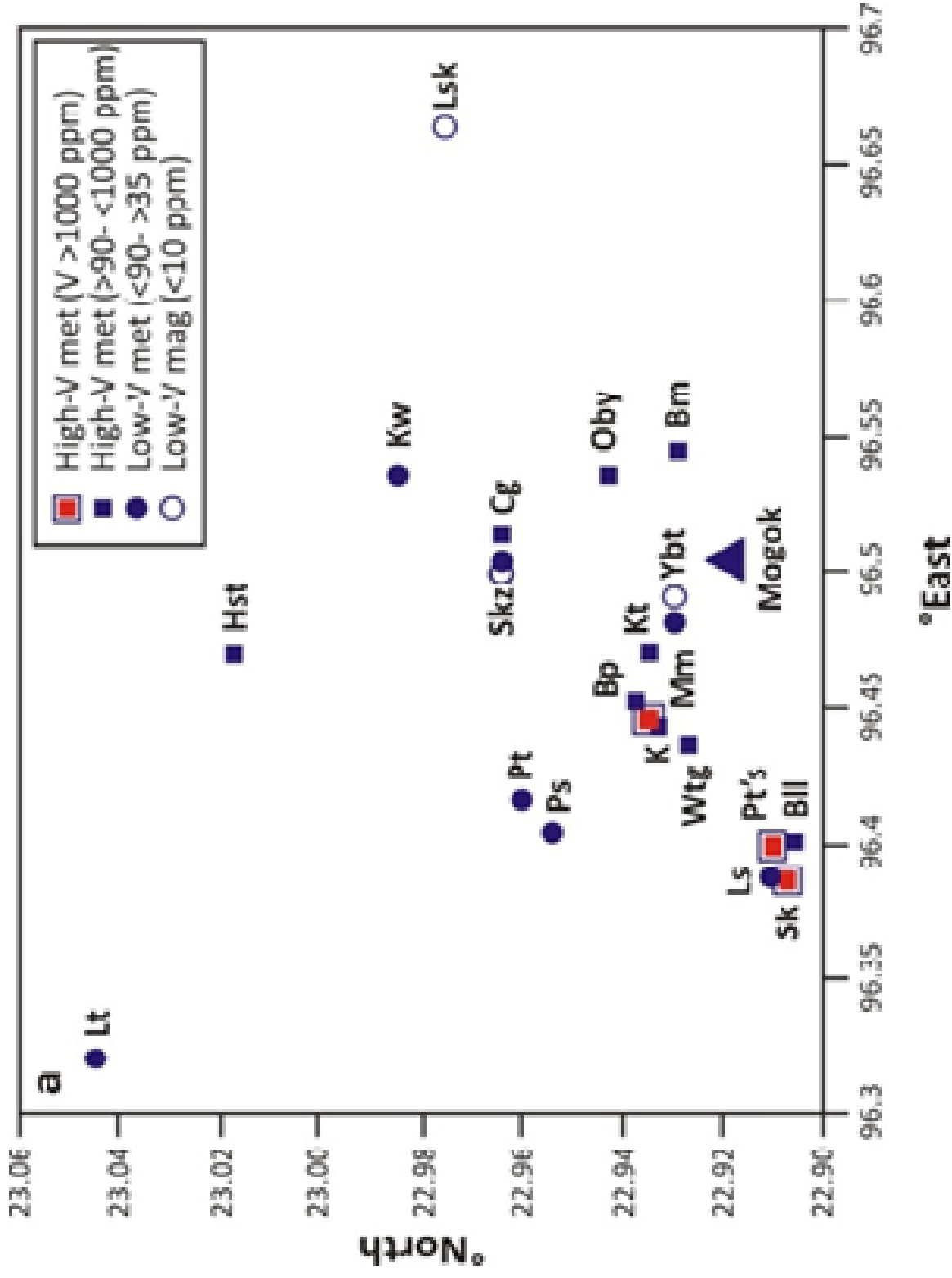


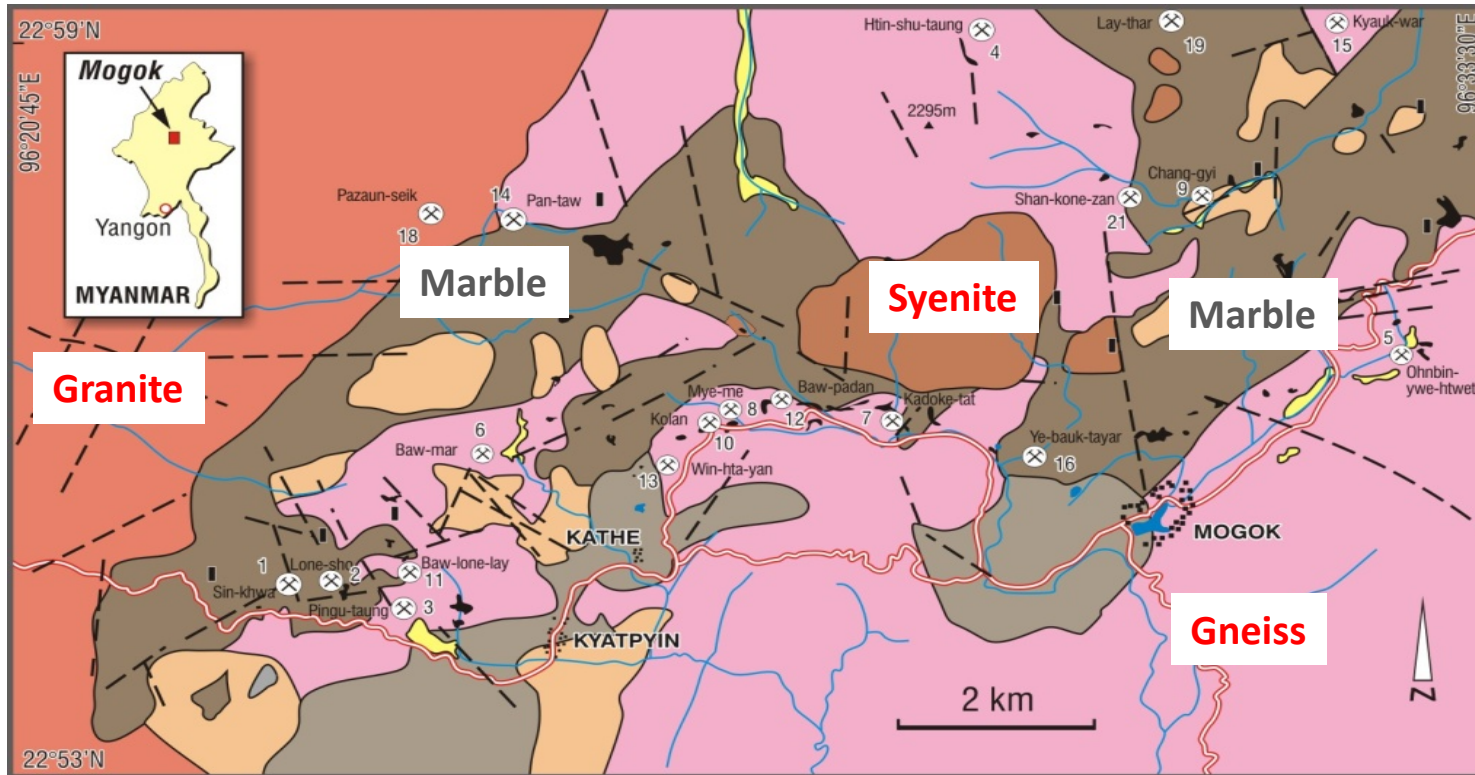












### LEGEND

|  |  |  |
|--|--|--|
|  Alluvium                               |  Quartzite                        |  Fault                    |
|  Leucogranite                           |  Marble (M1); Ruby-bearing marble |  Gem-bearing skarn        |
|  Biotite microgranite (Kabaing Granite) |  Marble (M2); Graphite marble     |  Gem mine/working studied |
|  Syenitic rocks                         |  Gneiss                           |  Village/Town             |
|  |  |  Roads                    |
|  |  |  Stream                   |
|  |  |  Peak (in metres)         |

# Conclusions



## Implications:

- Geographic typing
- Finger printing – DNA
- Source - Vanadium



Pagan  
10<sup>th</sup> Century  
Civilization

Thank you

