A new approach to the investigation of crustal evolution in complex terranes using statistical analysis of geochronology data

David R. Nelson
Department of Applied Physics
Curtin University of Technology
GPO Box U1987, Perth, Australia, 6000
d.nelson@curtin.edu.au

Granitic rock samples taken for geochronology may be regarded as random samples of large volumes of continental crust, with the age structure determined by U-Pb isotopic analysis of their zircon populations representative of the upper to lower crust at the time of granite emplacement. Evidence of ancient geological events may be preserved by the U-Pb system within zircons derived from the source rocks of granite melts, even though all rocks formed during these events may have been destroyed during granite generation. Dates obtained for a representative population of zircons from granitic samples collected from a sufficient number of randomly distributed sampling sites may allow reconstruction of both the spatial distribution of basement terranes, and the detailed histories of regional-scale magmatism and high-grade metamorphism. This contribution documents a new statistical approach, using a database of ion microprobe U-Pb zircon and monazite isotopic analyses obtained from granitic and sedimentary rock samples and the CONCH ion-microprobe data processing software package (Nelson, 2006), to the deconvolution of the regional-scale geological structure and history of a predominantly granitic terrane.

The study area includes the northwestern part of the Archaean Yilgarn Craton and southern part of the early to mid-Proterozoic Gascoyne Complex of western Australia. The database consisted of a total of 2159 published SHRIMP U-Pb analyses obtained on zircon and monazite grains extracted from 94 samples of granitic, granitic gneiss and metasedimentary rocks from the Belele, Byro, Collier, Glenburgh, Glengarry, Mount Phillips, Peak Hill and Robinson Range 1:250,000 map sheet areas. Of these, 165 analyses were more than 10% discordant and were excluded from the data pool. The remaining 1994 analyses were assigned to age groups using the following procedure. Radiogenic $^{207}Pb/^{206}Pb$ ratios, calculated using the ^{204}Pb correction method, were weighted according to the inverse square of the individual analytical uncertainty to determine a weighted mean $^{207}Pb/^{206}Pb$ ratio for pooled analyses. Uncertainties on individual analyses were based on counting statistics and uncertainties introduced by the common-Pb correction. Analyses were then rejected from the group using two criteria. A chi-square value was calculated for the grouped analyses. If the chi-square value was greater than a threshold value of 1.75, geological sources of uncertainty were assumed to be present within the group and the analysis whose $^{207}Pb/^{206}Pb$ ratio with assigned uncertainty was most different from the group weighted mean value was excluded from the group. In addition, any analysis whose $^{207}Pb/^{206}Pb$ ratio with uncertainty was beyond $\pm 2.5\sigma$ of the group weighted mean value was also deleted from the group. The weighted mean $^{207}Pb/^{206}Pb$ value of the remaining analyses was then recalculated. This process was repeated until all remaining analyses were within $\pm 2.5\sigma$ of the weighted mean $^{207}Pb/^{206}Pb$ value and the calculated chi-square value was below the threshold value. Analyses that belonged with a valid group were then excluded from the pool and process repeated until all remaining analyses had been grouped. This grouping method is statistically conservative, in that only the minimum number of clearly resolvable events based on the uncertainty limits assigned to each individual analysis will be identified. Uncertainties on $^{207}Pb/^{206}Pb$ ratios of individual analyses were typically between 5 and 10 Ma ($\pm 1\sigma$), comparable to or significantly larger than the uncertainties calculated for age groups. Analyses with assigned uncertainties overlapping more than one age group were usually assigned to the largest group, as larger groups were identified earlier during the grouping procedure. Using this procedure, all 1994 concordant analyses in the data pool were assigned to 139 age groups, of which the largest contained 278 analyses from 31 samples, and of which 48 groups contained only a single analysis. Of these, 120 analyses were assigned to groups with <3 analyses; these groups were considered to contain too small a sample to be of use and were discarded. A total of 1874 analyses, assigned to 72 groups containing >3 analyses, remained. Apart from one age group (2016 ±4 Ma; group uncertainties cited are 95% confidence limits) consisting of 4 analyses obtained from one sample, the remaining 71 age groups contained >3 analyses obtained from two or more samples. Most groups included analyses from a high number of samples, with an average [analyses/samples] ratio for all 72 groups of 2.4. Only four age groups (2625.2 ±1.4, 1995.5 ±1.1, 1804.0 ±1.8 and 1640.0 ±9.5 Ma) have [analyses/samples] ratios >5.

These findings are consistent with the generally high proportion of xenocryst zircons identified within the granitic rock samples and complex age populations within the granitic gneiss samples dated from the Study Area.

Sampling site localities and the spatial distribution of selected age groups are displayed in Figure 1. Most age groups identified by the statistical analysis are coherently distributed into regions delineated by their sampling localities. Distribution boundaries for age groups ≥3468.2 Ma are poorly located due to low sampling site density, but the northern boundary terminates south of the Earrabiddy Shear Zone. Age groups ≥3290.2 Ma are widespread south of a well-defined undulating east-west boundary parallel to the Earrabiddy and Morris Shear Zones. The close alignment of the ≥3290.2 Ma northern boundary and these shear zones indicates that the latter have exploited the northern margin of an ancient (≥3290.2 Ma) nucleus onto which the rest of the Yilgarn Craton was later accreted.

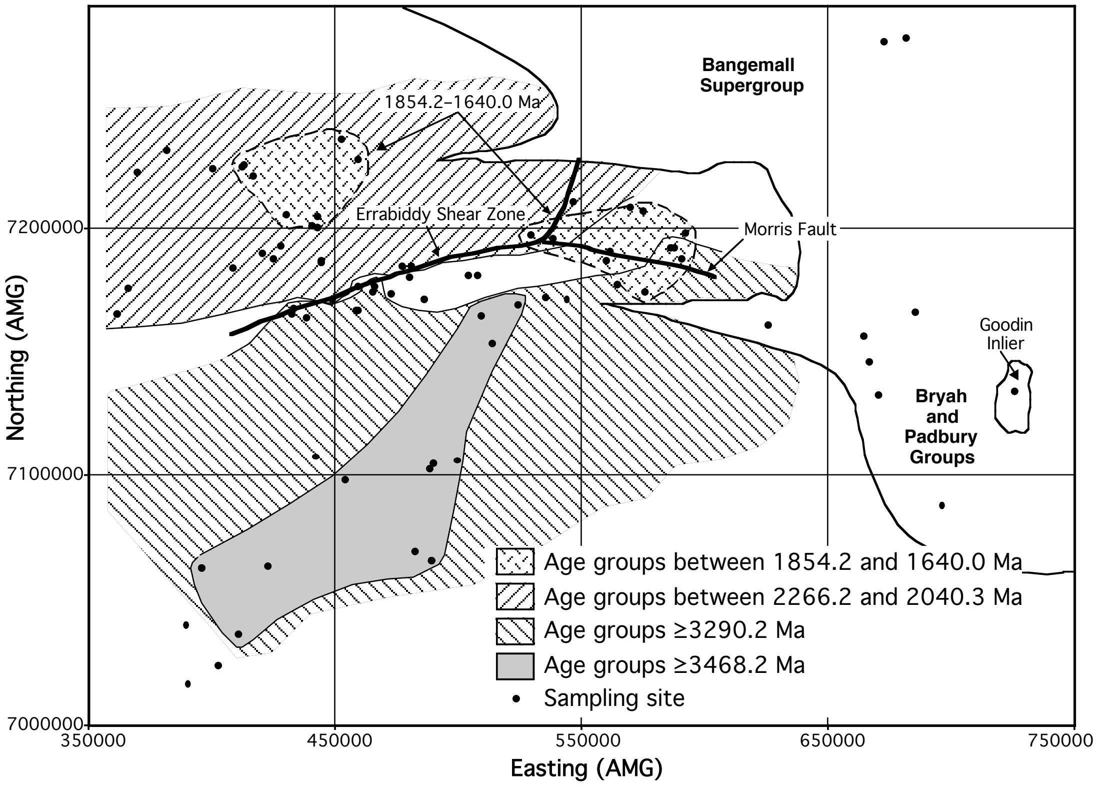

Figure 1. Locality map the northwestern Yilgarn Craton and southern Gascoyne Complex showing distribution of geochronology sampling sites used in this investigation, and of selected age groups.

Age groups between 3290.2 and 2538.6 Ma show a consistent distribution pattern, with the northern boundary defined by ≥3290.2 Ma age groups migrating progressively further northwards as the group age approaches 2538.6 Ma. Age groups between 3290.2 and 2917.4 Ma also occur within a narrow zone that extends as an arc to the north of the boundary in the northwestern part of the Study Area. This zone becomes progressively thicker and more clearly defined as younger age groups between 2917.4 and 2538.6 Ma are plotted. Age groups between 2266.2 and 2040.3 Ma are confined to the region north of the ≥2538.6 Ma boundary. Age groups between 2035.7 and 1917.2 Ma are also mainly confined to this region, but the southern boundary of these age groups migrates progressively southwards to overlap with the northern boundary of the ≥3290.2 Ma age group. Age groups between 1854.2 and 1640.0 Ma occur within two main areas; these areas may unite as the sampling site density is increased.

This approach reveals how both the spatial distribution of basement terranes and the detailed histories of regional-scale magmatism and high-grade metamorphism may be reconstructed. The approach can also delineate the most prospective area for locating the Hadaean crustal source, if any has survived, of the ≥4000 Ma zircons identified in the Narryer and Jack Hills metasedimentary belts and Murchison granitoid rocks.

References

Nelson, D.R. (2006) CONCH: a versatile Visual Basic program for the interactive processing of ion-microprobe data. Computers and Geosciences 32, 1479-1498.