SEDIMENT RECYCLING
REVEALED BY COMMON Pb ISOTOPES IN K-FELDSPAR

Introduction

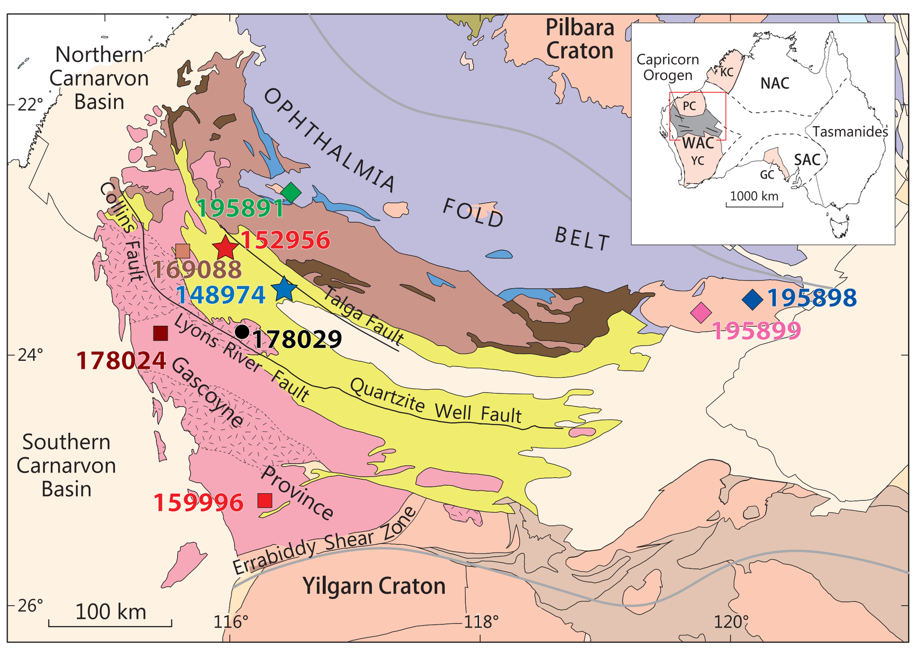
Comparing the age and chemical or isotopic signature of minerals in sedimentary rocks to those in potential basement hinterlands is a fundamental tool used to fingerprint source to sink relationships. Detrital zircon geochronology has evolved as the choice for provenance studies because zircon grains are ubiquitous in sandstones, highly resistant to both chemical and physical weathering, amenable to U–Pb dating and carry other isotopic and chemical signatures (e.g. Lu–Hf, REE) that may uniquely link a zircon grain to its basement source. However, although the refractory nature of zircon provides the benefit of recording much of the high-temperature history of a geological terrane, its resistance to erosion provides a challenge to provenance reconstruction as it can be recycled a multitude of times.

In a recent review paper it was stated "**that for provenance studies, the good news is once in the system, zircons stay in the system; and the bad news is once in the system, zircons stay in the system**".

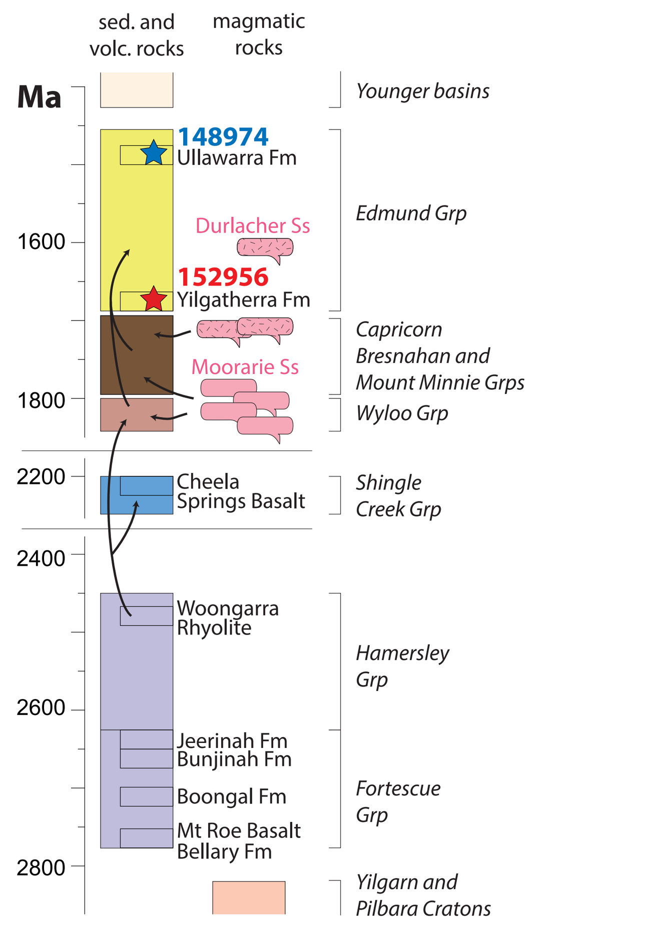
One elegant approach to address the primary source to sink relationship is to compare the common Pb isotopic signature of detrital K-feldspar, a mineral unlikely to survive more than one erosion-transport-deposition cycle, with the signature of potential source basement terranes. K-feldspar is a common mineral in many clastic rocks and is a major constituent of arkosic sandstones. Lead isotope variations ($^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$) in igneous and metamorphic crustal rocks define broad spatial patterns that make the Pb signature of detrital K-feldspar grains a useful provenance tool. Regional patterns in Pb isotopic composition can be identified by characterizing a relatively small number of feldspar grains from potential granitic basement sources.

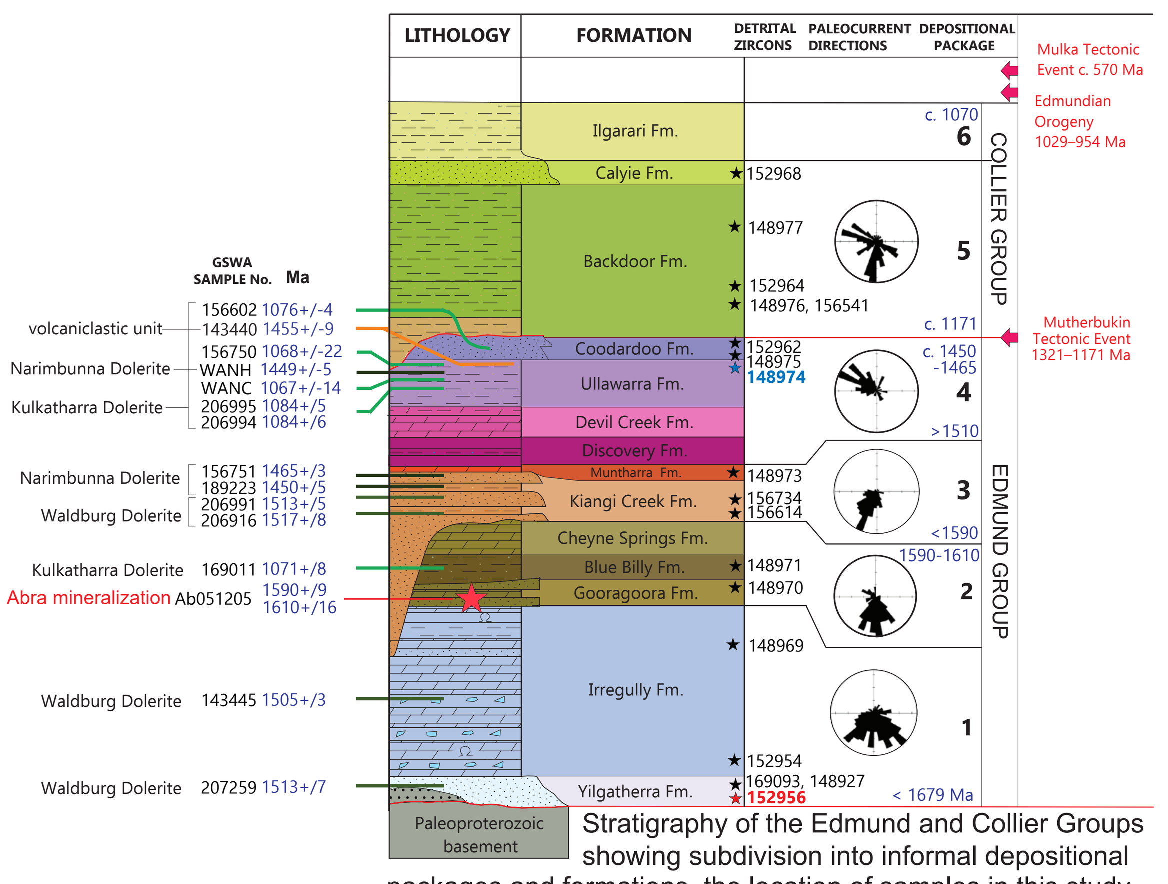
The Edmund Group

The Paleo- to Mesoproterozoic Edmund Group in the Capricorn Orogen of Western Australia is dominated by sandstone units containing detrital zircons that are similar in age and isotopic composition to the underlying basement magmatic rocks of the Gascoyne Province. However, abundant, well-developed paleoflow indicators throughout the basin suggest a primary source outside the province to the north, implying that the zircon detritus has been recycled, presumably through older sedimentary basins. In this study we report the common Pb isotopic signature of detrital K-feldspar from two arkosic sandstones in the group, and compare the results to the composition of magmatic K-feldspar from various basement granitic rocks in order to address this dichotomy and further elucidate source to sink relationships in this basin.



Simplified geological map of the Capricorn Orogen of Western Australia, showing the location of samples studied. The geological legend (right) is provided as a stratigraphic column which shows possible pathways for recycling of detrital zircons.

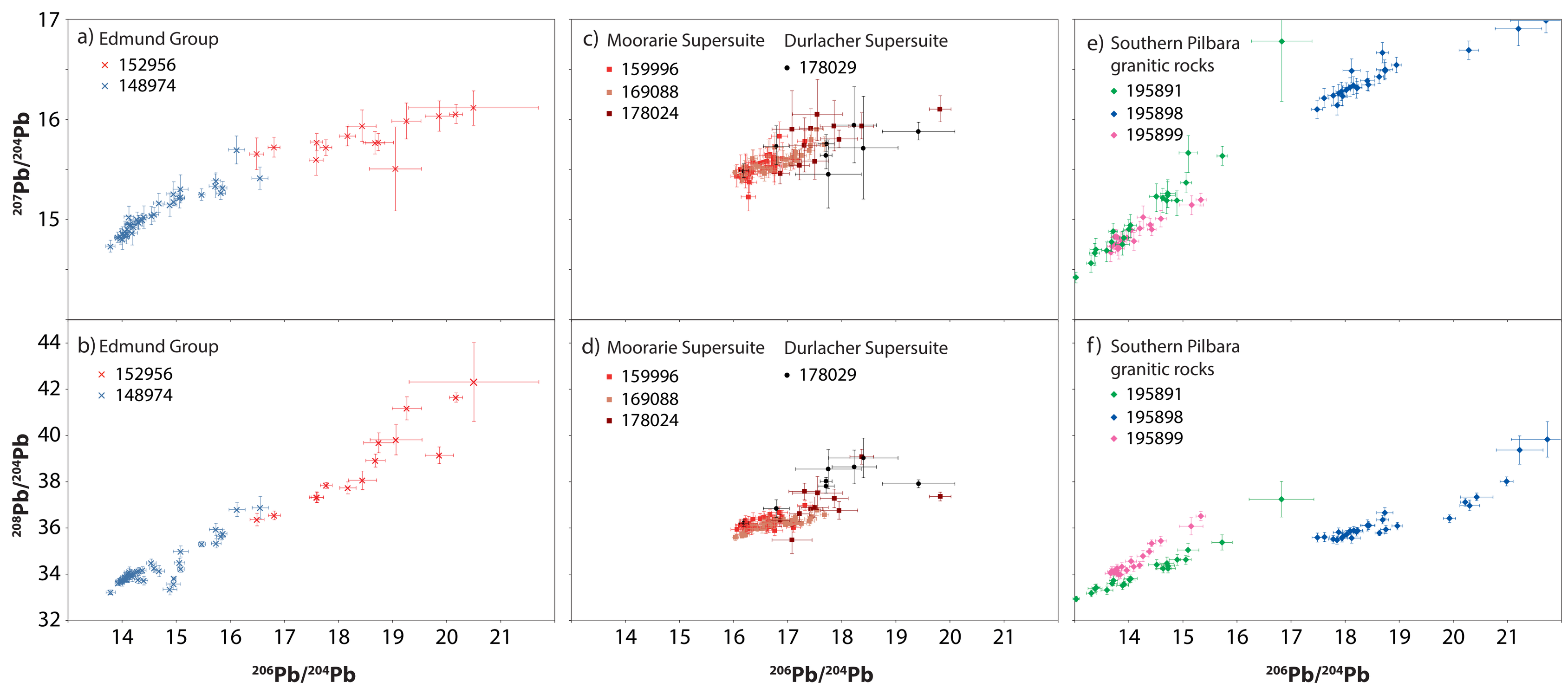




Stratigraphy of the Edmund and Collier Groups showing subdivision into informal depositional packages and formations, the location of samples in this study, and rose diagrams showing paleocurrent directions (Martin et al., 2008).

The Edmund Group is a mixed siliciclastic and carbonate sedimentary unit up to 9.5 km thick, comprising predominantly sandstone and siltstone, with subordinate conglomerate, dolostone, stromatolitic dolostone, carbonaceous siltstone and chert. The sedimentary rocks were deposited in a variety of fluvial to marine shelf or basinal environments, the distribution of which was strongly controlled by fluctuations in relative sea-level and syn-sedimentary movement on major, pre-existing basement faults. The group has been divided into four, informal depositional packages that includes 11 formations, from base to top: the Yilgatherra, Irregully, Gooragoora, Blue Billy, Cheyne Springs, Kiangi Creek, Muntharra, Discovery, Devil Creek, Ullawarra and Coodardoo Formations. Each package is defined by a basal unconformity or a major marine flooding surface, both of which are the result of differential fault movements or fluctuations in sea level.

Pb isotope compositions of detrital and magmatic K-feldspar



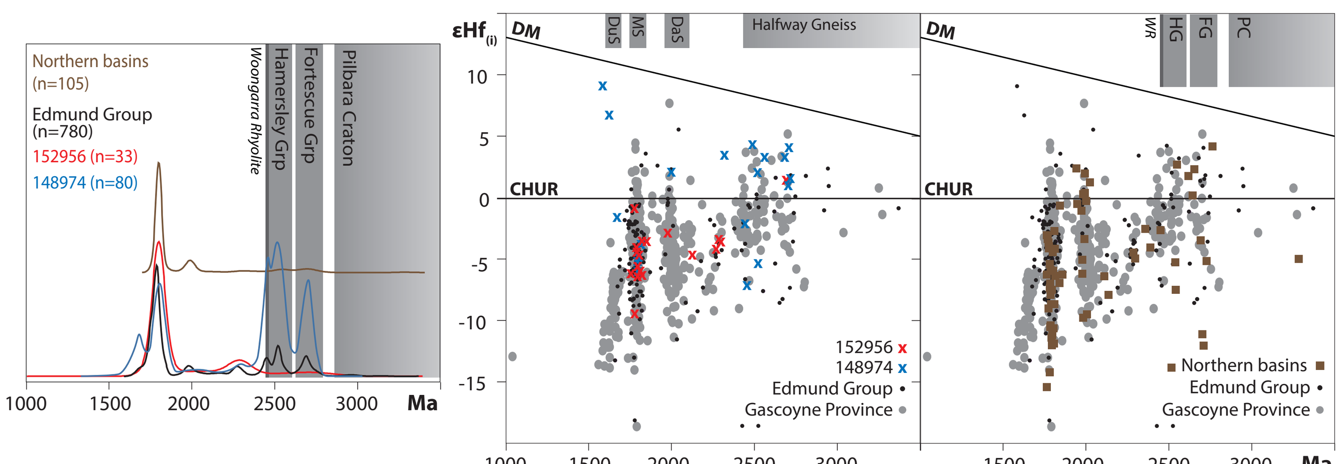
Pb isotope composition of detrital K-feldspar from the (a, b) Edmund Group, and magmatic K-feldspar from felsic magmatic rocks of the (c, d) Gascoyne Province and (e, f) southern Pilbara region.

Detrital K-feldspar from two samples of arkosic sandstone from the Edmund Group and magmatic K-feldspar from four samples of felsic magmatic rocks from the underlying Gascoyne Province and three from the southern Pilbara were analysed for their Pb isotope compositions. A total of 211 Pb isotopic analyses were collected from 211 K-feldspar crystals. Zones of alteration and inclusions identified by SEM-imaging were avoided during the laser ablation analysis.

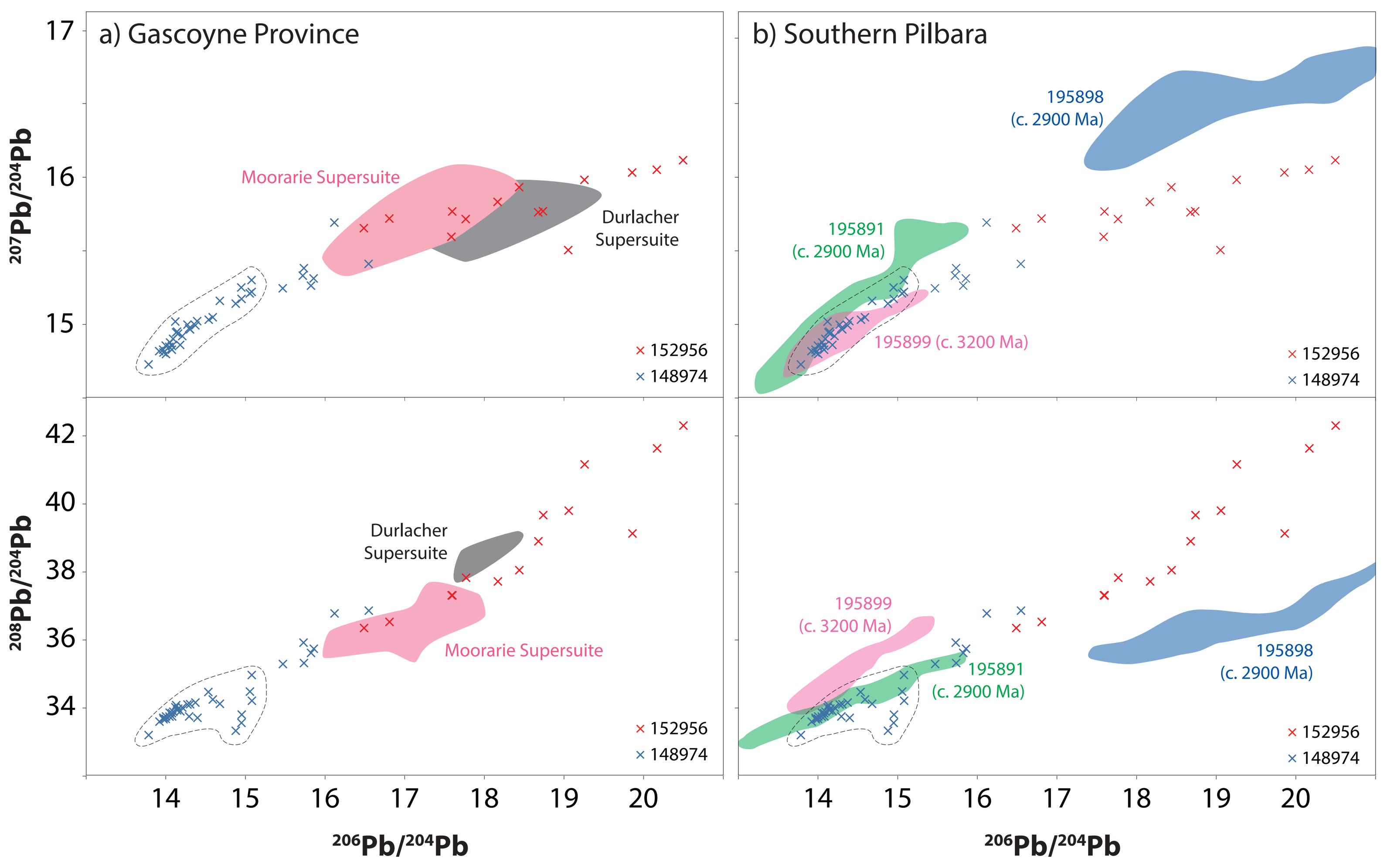
The detrital K-feldspar yield a wide range of $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ compositions similar to the basement granitic rocks of the southern Pilbara, whereas the granitic rocks of the Gascoyne Province yielded a relatively narrow, and well-contrained range of Pb isotope compositions that are significantly different in composition to the detrital grains. This indicates that the detrital K-feldspar could not have been sourced from the Gascoyne Province magmatic rocks.

Implications for source provenance

The age and Hf isotopic composition of detrital zircons from the two arkosic sandstones, as well as from other sedimentary rocks of the Edmund Group, suggest that the zircon detritus was derived predominantly from the 1820–1775 Ma Moorarie Supersuite (MS), with minor components from the 1680–1620 Ma Durlacher Supersuite (DS) and some older rocks of the Gascoyne Province.

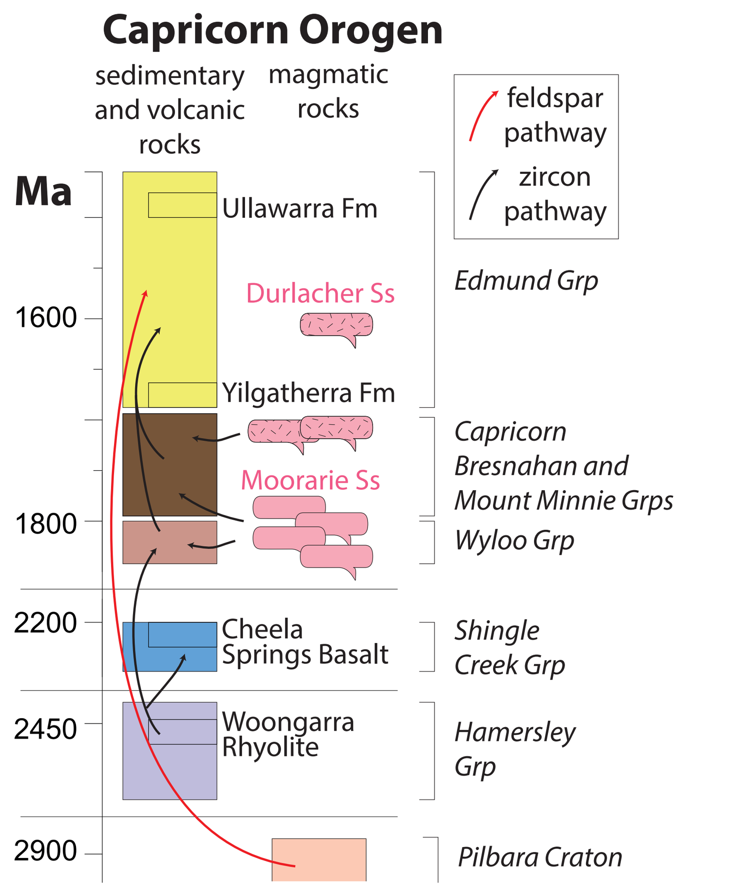


Kernel density estimates for the age of detrital zircons from the studied samples and Edmund Group, and from older basins in the northern Capricorn Orogen (Northern basins) including the Capricorn, Bresnahan and Mount Minnie Groups. εHf(t) compositions of detrital zircons fromthe Edmund Group compared to magmatic zircon compostions from the underlying Gascoyne Province and the Northern basins. DaS-Dalgaringa Supersuite; DuS-Durlacher Supersuite; FG-Fortescue Group; HG-Hamersley Group; MS-Moorarie Supersuite; PC-Pilbara Craton; WR-Woongarra Rhyolite.



Summary of Pb isotope compositions of detrital K-feldspar in the sedimentary rocks versus the magmatic grains in the potential magmatic source rocks of the (a) Gascoyne Province and (b) southern Pilbara region.

However, the Pb isotope compositions of the detrital K-feldspar within these sandstones do not match those from the potential granitic source rocks of the Gascoyne Province, particularly in the $^{206}Pb/^{204}Pb$ verses $^{208}Pb/^{204}Pb$ system. This indicates that despite these rocks containing a major cargo of detrital zircon derived from the Gascoyne Province, these basement rocks could not have been the direct source of the sediment detritus. Instead, the detrital K-feldspar compositions closely match those of Archean granitic rocks from basement inliers along the southern Pilbara margin suggesting that this region was the primary source of detritus feeding the Edmund Basin.



Stratigraphic column showing the potential pathways for zircon cycling verses the direct pathway of K-feldspar in the first cyle detritus.

The K-feldspar common Pb isotope data and detrital zircon U–Pb data together suggest that the Edmund Basin was fed with detritus derived directly from the southern Pilbara margin with most zircon being recycled through older sedimentary basins such as the Capricorn, Bresnahan and Mount Minne Groups (Northern basins). This interpretation is consistent with macroscopic paleoflow indicators which suggest flow from upland regions to the north of the Edmund Basin.

The results are significant because they help redefine the tectonic history of the region. The data indicate that during the latter stages of the extensional Mangaroon Orogeny, the northern margin of the orogen was subject to uplift and erosion. Detritus was shed toward the south into the Edmund Basin, which developed in the central part of the orogen as a continued expression of this extensional event. The southern part of the orogen however, remained passive, a conclusion that could not have been made from the detrital zircon data alone. This interpretation is supported by new in situ U–Th–Pb phosphate dating showing that, during this event, the northern margin of the orogen was subject to repeated fault reactivation, low temperature hydrothermal fluid flow and associated gold mineralization (Fielding et al., 2017).

References:
Fielding et al., 2017. Economic Geology 112, 1205–1230. Martin et al., 2008. Precambrian Research 166, 93–110.

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