The age and provenance of the Mosquito Creek Formation

by L. Bagas, T. R. Farrell, and D. R. Nelson

Abstract

Sensitive high-resolution ion microprobe (SHRIMP) U–Pb detrital zircon ages and galena Pb–Pb model ages from the Mosquito Creek Formation indicate an age of deposition between c. 2926 Ma and c. 2905 Ma. Comparison of detrital zircon data with the age-distribution patterns for other Pilbara terranes indicate that conglomerate at the base of the formation had a provenance that included the East Pilbara Granite–Greenstone Terrane. However, a significant component of the upper part of the formation must have had a source from elsewhere, possibly either from the Sylvania Inlier to the southwest or an unknown terrane to the east.

KEYWORDS: North Pilbara Craton, Archaean, Mosquito Creek Formation, detrital zircon geochronology.

Introduction and regional setting

The Mosquito Creek Formation (Maitland, 1908; Noldart and Wyatt, 1962; Hickman, 1983) is a succession of Archaean siliciclastic rocks that occupies much of the central part of the Mosquito Creek Basin in the northern part of the Archaean Pilbara Craton of Western Australia (Fig. 1). The formation is multiply deformed and has been metamorphosed under low-grade conditions.

Hickman (2001) subdivided the north Pilbara Craton into the c. 3270–2920 Ma West Pilbara Granite–Greenstone Terrane (WPGGT), Central Pilbara Tectonic Zone (CPTZ), c. 3650–2830 Ma East Pilbara Granite–Greenstone Terrane (EPGGT), the Mosquito Creek Basin, and the little-known Kurrana Terrane (KT). The CPTZ and EPGGT include the c. 2970–2920 Ma De Grey Supergroup (Van Kranendonk et al., 2004 — this Annual Review). The exposed part of the Mosquito Creek Basin is approximately 60 km long and 30 km wide (Figs 1 and 2).

The De Grey Supergroup was deposited in a number of isolated but broadly contemporaneous clastic sedimentary packages across the north Pilbara Craton (Fig. 1). This supergroup includes rocks of the Mallina Basin in the northwest, Paradise Plains Formation in the north, Lalla Rookh Sandstone in the central part of the EPGGT, and the Mosquito Creek Basin in the southeast (Fig. 1). To the south, the Mosquito Creek Basin is wedge shaped in cross section (S. Shevchenko, GSWA, unpublished data), and is separated from the c. 3200–2840 Ma Kurrana Granitoid Complex by the Kurrana Shear Zone (Bagas, in prep.).

Hickman (1984) interpreted the Mosquito Creek Basin to have formed through subsidence during the later stages of granitic diapirism in the east Pilbara, but Eriksson et al. (1994) interpreted it as a forearc basin and accretionary complex situated to the north of a subduction complex. Tyler et al. (1992) interpreted the Kurrana Shear Zone as a suture between two distinct terranes that amalgamated between 3000 and 2760 Ma (Fig. 2). Krapez and Eisenlohr (1998) suggested that the Mosquito Creek Basin is equivalent in age to the c. 3240 Ma Gorge Creek Group, but Witt et al. (1998) interpreted it to be contemporaneous with the De Grey Supergroup.

This study presents new constraints on the age and provenance of the Mosquito Creek Formation based on SHRIMP U–Pb dating of detrital zircons. Zircons are durable and can survive the processes of weathering and erosion, are largely unaffected by metamorphism below amphibolite facies, and can survive transport over distances of many hundreds or even thousands of kilometres (e.g. the Amazon deltaic fans of South American with sediments derived from the Andes). The distribution of U–Pb ages of detrital zircons can also give valuable clues to provenance (e.g. Bagas et al., 2002).

Mosquito Creek Basin

In the Mosquito Creek Basin (MCB) the Coondamar Formation is present along its southern and northeastern margins (Bagas, in prep.; Farrell, in

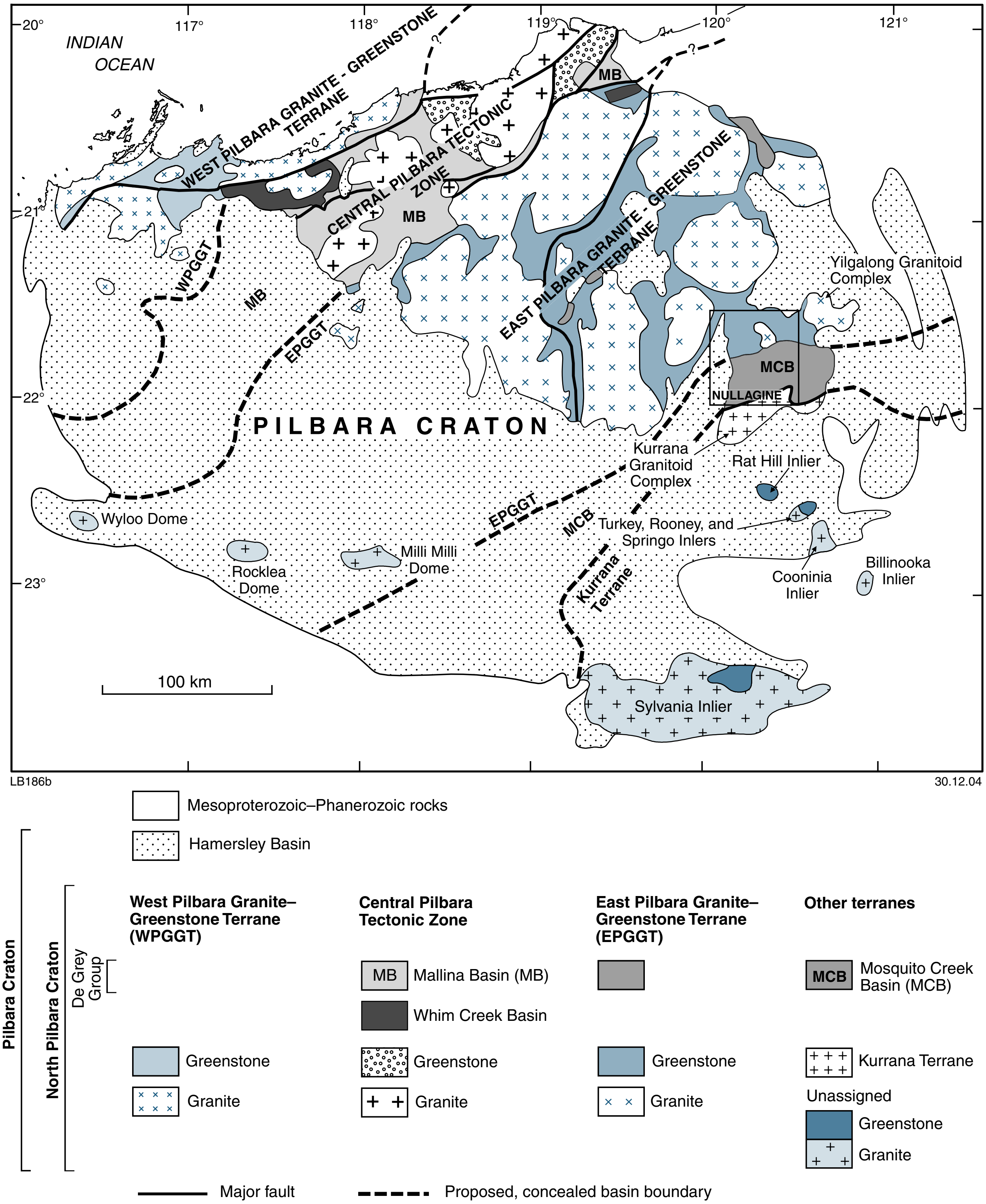

Figure 1. Regional geological setting of the Mosquito Creek Basin in the northern Pilbara Craton. The figure shows the proposed easterly to northeasterly configuration of the basin beneath the Hamersley Basin, which is based on an interpretation by Hickman (2004) using published regional-scale gravity and magnetic data (Blewett et al., 2000)

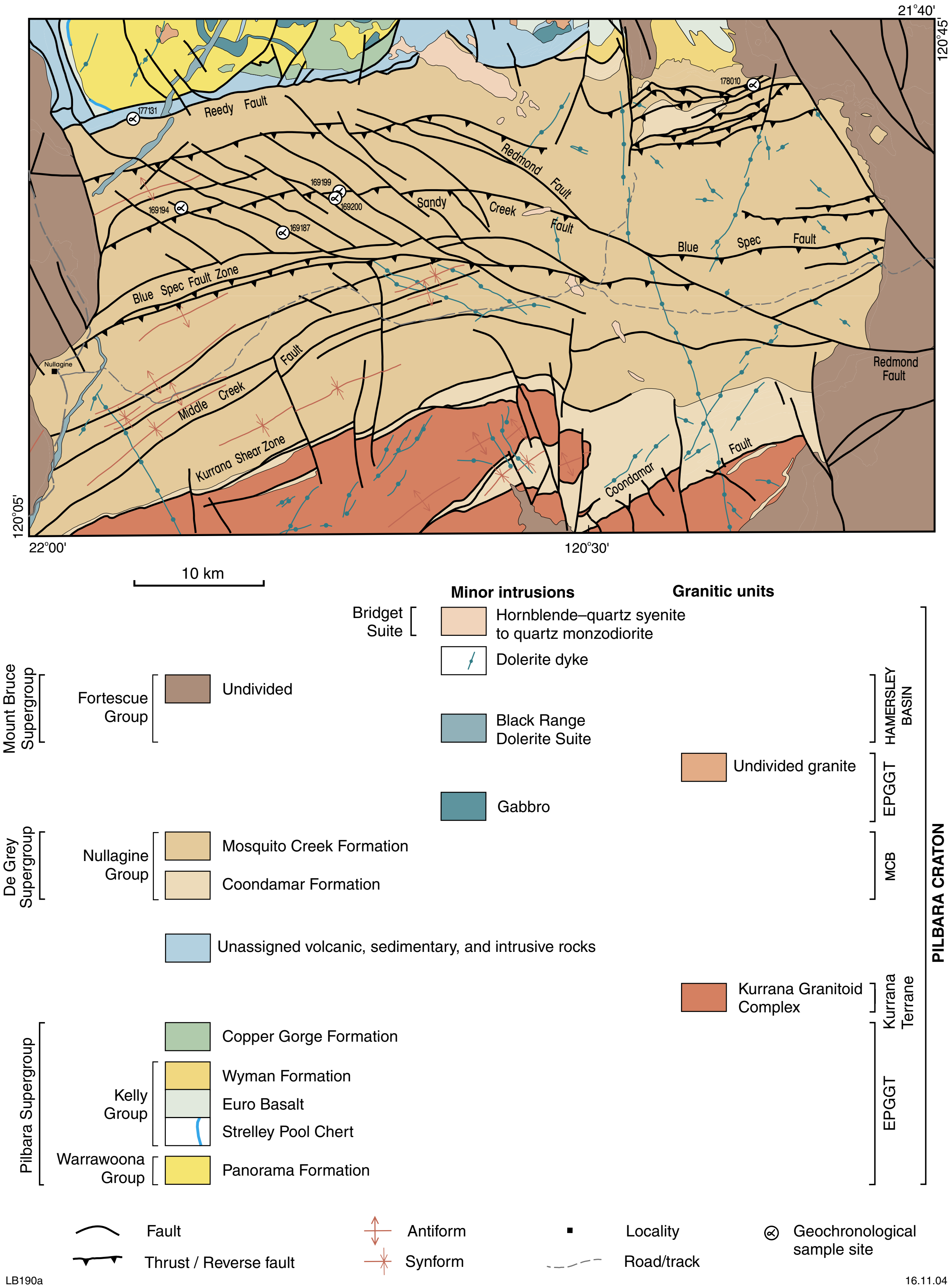

Figure 2. Generalized geological map of the exposed part of the Mosquito Creek Basin, showing the location of geochronological sample sites

Table 1. Deformational events recognized in the Mosquito Creek Basin

Event	*Age (Ma)*	*Structures*	*Tectonics*	*Comments*
D_1	<2950	S_1 fabric, steeply plunging mineral lineation	West-over-east ?thrusting (MCF[a] over ?CF[b])	Metamorphic peak between D_1 and D_2
D_2	c. 2900	Major ENE–WSW folds, S_2 penetrative slaty cleavage, NNW–SSE thrusting, crenulation lineation, weak NNW-plunging mineral lineation	SSE-over-NNW thrusting	Steepening of faults in centre and south (back ?rotation). Probably correlates with the main fabric in the Mallina Basin. Faults associated with this event host Au and base metal mineralization in MCB[c] (Blewett et al., 2002)
		Thrust and reverse faults late in D_2		Disruption of isograds late in D_2
D_3	< c. 2860	S–C fabrics in shear zones, asymmetric boudins	Dextral shearing (MCF and CF)	Possible reactivation of late-D_2 thrust faults. Post-dates BDG[d] in KT[e]
D_4	< 2860	North–south kink folds and kink bands, upright local crenulation cleavage (S_4)	East–west shortening	Last widespread event. Conjugate crenulation cleavages (trending 000–020° and 040°)
D_5	< 2690	Folds adjacent to steeply dipping faults: 5a. North to northwest 5b. West to northwest	 5a. Step down to east (oblique slip) 5b. Sinistral (north side up)	Probably in response to NE–SW compression

NOTES: (a) Mosquito Creek Formation
(b) Coondamar Formation
(c) Mosquito Creek Basin
(d) Bonney Downs Granite
(e) Kurrana Terrane

SOURCE: Farrell and Bagas (in prep.)

prep.), and is conformably overlain by the Mosquito Creek Formation (Fig. 2). These rocks are intruded by Archaean and Palaeoproterozoic igneous rocks, and have been subjected to five deformation events (Table 1).

In the northeastern part of the Mosquito Creek Basin (Fig. 2), the Coondamar Formation consists of lithic sandstone containing subangular to subrounded basaltic clasts. In the southern part of the basin, the formation consists of chloritic metasedimentary rocks, metachert, metagabbro, and amphibolite.

The Mosquito Creek Formation forms the remainder of the Mosquito Creek Basin succession (Figs 1 and 2). The total thickness of the formation cannot be accurately determined owing to the lack of suitable marker units, and because its top is not exposed. Hickman (1983) proposed that it is about 5 km thick, but this is probably an overestimation due to tight folding and structural repetition.

Along the northern edge of the basin, the basal 100 m of the Mosquito Creek Formation consists of a succession of interbedded conglomerate, massive coarse-grained sandstone, siltstone, and shale that unconformably overlies, or is in faulted contact with, the EPGGT. Individual conglomerate beds are channel deposits up to about 10 m thick, and contain rounded greenstone clasts of vein quartz, chert, and basalt, and rare felsic volcanic rocks up to about 200 mm across, in a poorly sorted sandstone matrix. The conglomerate beds are poorly sorted, coarse grained, and are sometimes interbedded with cross-bedded pebbly sandstone. The sandstone is moderately sorted, containing subrounded chert and quartz pebbles, and well-rounded to subrounded grains of quartz, chert, white mica, feldspar, and rare biotite. Eriksson et al. (1994) suggested that the succession was probably deposited in a submarine fan system.

The upper part of the Mosquito Creek Formation consists of thinly bedded sandstone interbedded with siltstone and shale, and has been metamorphosed at sub-greenschist to lower greenschist facies. The sandstone beds are typically fine to medium grained, well graded, and the only tractional structures observed are a weak horizontal lamination and rare ripple marks. Sandstone beds typically have a sharp base, with localized scour structures, and the lack of hummocky cross-bedding suggests a deep-water depositional environment. The contact with overlying siltstone and shale is commonly gradational, and full Bouma cycles are locally present. The sandstone contains a variety of angular to subrounded clasts of quartz, feldspar, chert, intraformation sandstone and shale, and rare felsic igneous rocks and quartz–sericite schist, in a finer grained pelitic matrix. The matrix characteristically consists of metamorphic white mica, chlorite, carbonate, rutile, very fine grained disseminated pyrite, and quartz, with detrital grains of quartz, white mica, and feldspar. The sandstone beds have been classified by Eriksson et al. (1994) as lithic wacke and lithic arenite, and interpreted as turbidites by Hickman (1983).

Age constraints for the Mosquito Creek Basin

A single Pb–Pb model age of 2905 ± 9 Ma records a lode gold mineralizing event in the Mosquito Creek Formation (Thorpe et al., 1992; Table 2), and constrains the minimum age of the host formation. This event appears to be synchronous with 2905 ± 9 Ma base metal mineralization in the Coondamar Formation (Huston et al., 2002; Table 2), which suggests that there was a widespread mineralizing event at c. 2905 Ma in the Mosquito Creek Basin. This event was also broadly synchronous with the emplacement of 2897 ± 6 Ma monzogranite and granodiorite in the Cooninia Inlier (Geological Survey of Western Australia, 2004), about 100 km to the south of the basin (Fig. 1).

U–Pb detrital zircon age constraint for the Mosquito Creek Formation

To better constrain the maximum age for the Mosquito Creek Formation, 195 detrital zircons were dated by D. R. Nelson (Geological Survey of Western Australia, 2004, in prep.) from six samples of medium- to coarse-grained sandstone collected from the northern and eastern outcrops of the formation (Fig. 2). Due to structural complexities it is not possible to place the samples on a single stratigraphic column. The procedures used in rock sampling, and concentrating and selecting detrital zircons for dating, are described in detail by Nelson (1997, 1999).

The youngest group of detrital zircons has an age of 2926 ± 29 Ma, and was obtained from sandstone interbedded with conglomerate near the base of the formation (GSWA sample 177131, Fig. 2). It indicates a maximum depositional age of about 2926 Ma. If the two Pb–Pb model ages of 2905 ± 9 Ma obtained from the Mosquito Creek and Coondamar Creek deposits are regarded as being accurate (Table 2), the depositional age of the formation is probably between 2905 and 2926 Ma.

Provenance

Relative cumulative-probability plots are commonly used to visually assess the statistical similarities or differences between samples and potential source regions (e.g. Camacho et al., 2002). The plots present summed probability density curves for concordant analyses (i.e. those analyses for which there is a 95% confidence level that the $^{206}Pb/^{238}U$ age is within the uncertainty of the $^{207}Pb/^{206}Pb$ age), assuming that the probability density of each analysis follows a Gaussian distribution. The horizontal spread in the graphs for each peak relates to the standard deviation, and generally reflects the accuracy of the data. Such plots for the samples from the Mosquito Creek Formation reveal that the Mosquito Creek Basin had a provenance supplying c. 2926 Ma to c. 3730 Ma zircons (Fig. 3). By comparing data against the pooled data for the WPGGT and EPGGT, it becomes apparent that the provenance for the basin was not entirely the north Pilbara Craton (Fig. 4).

A significant proportion of the detrital zircons dated from the Mosquito Creek Formation are appreciably older than the pooled zircon data for the WPGGT (Fig. 4), and the detrital zircon age distribution data do not correlate well with the pooled zircon data for the EPGGT. For example, prominent peaks at c. 3540, 3360 and 3090 Ma in the profile for the Mosquito Creek Formation are not represented in the plot for the EPGGT (Fig. 4). The implication is that the main hinterland for the Mosquito Creek Basin was an area other than the exposed north Pilbara Craton and one that contains zircons with ages of c. 3540, 3360, and 3090 Ma.

When the detrital zircon data for the samples from the Mosquito Creek Formation are considered individually (Fig. 3), two groups emerge. One group comprises two samples (GSWA samples 177131 and 178010) from the submarine fan deposits at the base of the formation, and the other group includes the remaining samples (GSWA samples 169200, 169199, 169194, and 169187). Samples 177131 and 178010 have distribution peaks at c. 3470 and 3425 Ma and a trough at c. 3370 Ma, similar to the age profile for the EPGGT. A

Table 2. Pb–Pb model ages on galena from mineral deposits in the Mosquito Creek Basin

Deposit	*Location MGA, Zone 51K*	*Description*	*Analytical technique*	*Age (Ma)*	*Reference*
Mosquito Creek in the Mosquito Creek Formation	237565E 7586430N	Galena from gold-bearing quartz veins hosted by D_2 structures in pelitic schist	Conventional	2905 ± 9	I. R. Fletcher, quoted in Thorpe et al. (1992)
Coondamar Creek in the Coondamar Formation	258931E 7572090N	Sulfide deposit (containing sphalerite, chalcopyrite, pyrite, and minor galena) interbedded with black shale	Conventional	2905 ± 9	Huston et al. (2002)

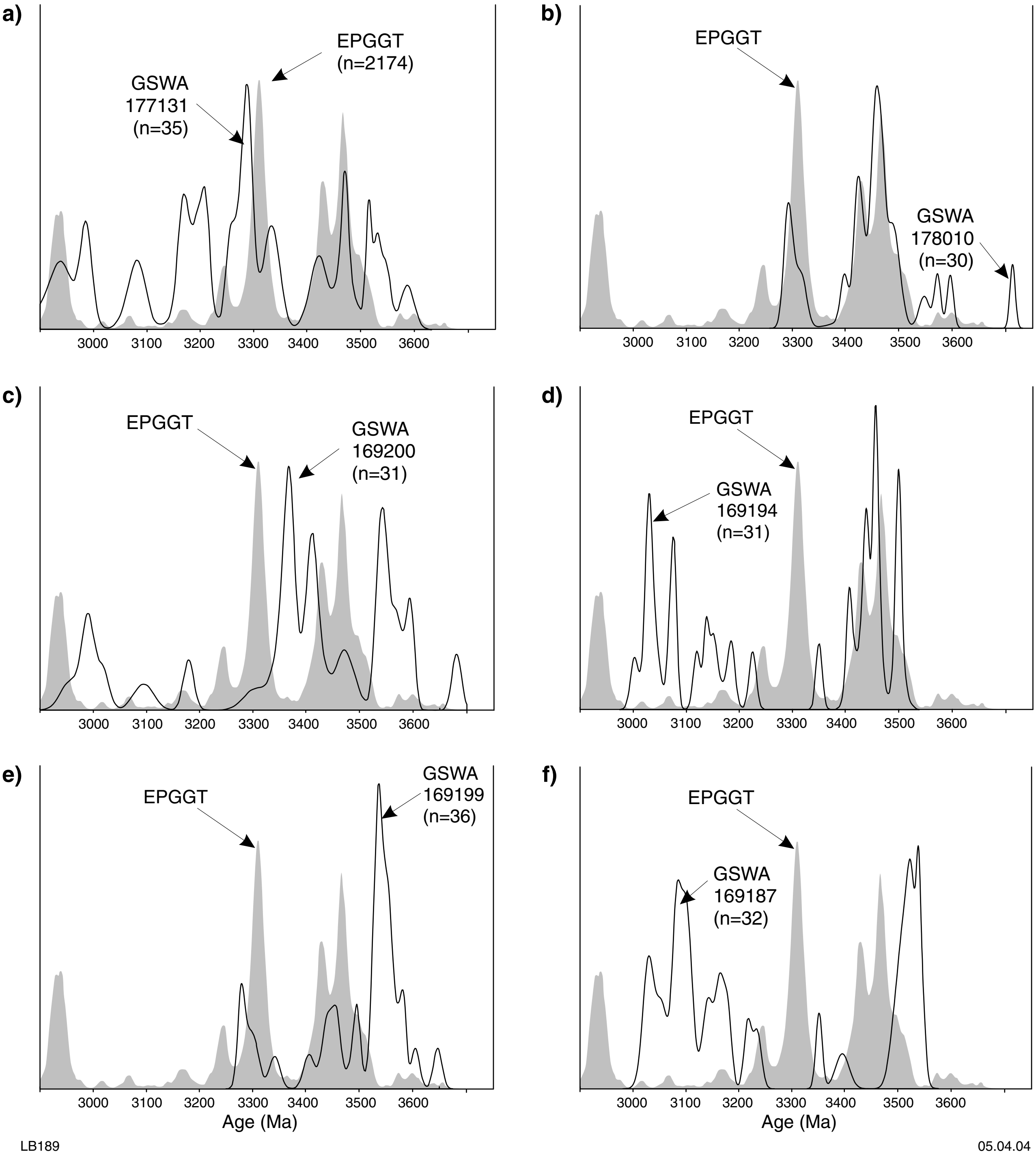

Figure 3. Relative cumulative-probability diagrams of SHRIMP U–Pb zircon ages from the Mosquito Creek Formation (Geological Survey of Western Australia, 2004) and the East Pilbara Granite–Greenstone Terrane (EPGGT) (Nelson, 1996, 1997, 1998, 1999, 2000, 2001, 2002; Geological Survey of Western Australia, 2004) for: a) GSWA sample 177131; b) GSWA sample 178010; c) GSWA sample 169200; d) GSWA sample 169194; e) GSWA sample 169199; and f) GSWA sample 169187. Samples a) and b) are from the basal conglomerate, and the other samples are from the upper part of the formation. The age uncertainties are at the 95% confidence level for the concordant populations of zircons used in the construction of these graphs, and the internal precision for single analyses is 1σ (n = number of analyses)

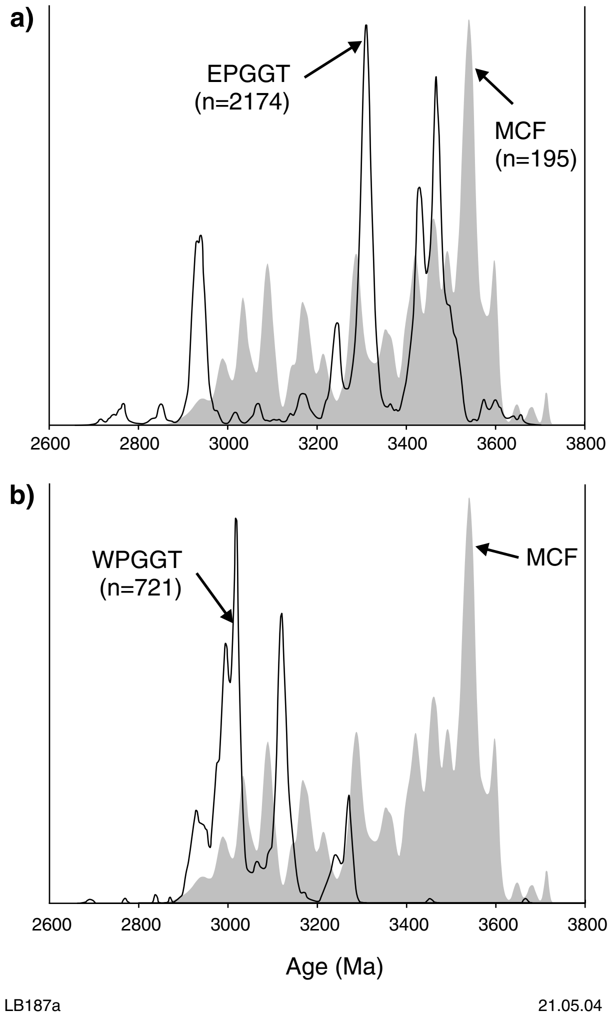

Figure 4. Relative cumulative-probability diagrams of pooled SHRIMP U–Pb zircon ages from the Mosquito Creek Formation (MCF) compared to a) East Pilbara Granite–Greenstone Terrane (EPGGT) and b) West Pilbara Granite–Greenstone Terrane (WPGGT). The age uncertainties are at the 95% confidence level for the concordant populations of zircons used in the construction of these graphs, and the internal precision for single analyses is 1σ (n = number of analyses)

peak in both samples at c. 3290 Ma is consistent with new data for the Yilgalong Granitoid Complex in the EPGGT (Geological Survey of Western Australia, in prep.; Fig. 1). However, the samples also have peaks at c. 3540 and 3200 Ma that are not represented in the plot for the EPGGT. This suggests that the basal fan deposits had a mixed provenance that did not include the EPGGT alone.

The second group contains samples from the upper turbiditic part of the Mosquito Creek Formation. The samples have slightly differing zircon age profiles (Fig. 3), but there are common peaks at c. 3540, 3490, 3360, 3280, 3220, 3140, 3040, and 3000 Ma in some or all of the samples, none of which are common in the plot for the EPGGT. Conversely, peaks at c. 3470 and 3430 Ma in the samples from the base of the formation are not represented in the zircon distributions for the upper part of the formation. These observations suggest that the EPGGT contributed detritus to the stratigraphically lower part of the Mosquito Creek Formation, but did not form a significant source of detritus for the upper part of the formation.

Discussion

The combination of the large volume of the sediment now forming the bulk of the Mosquito Creek Formation (less than 5 km thick), the immaturity of the sediment, and the fine-grained nature of the sandstone in the formation indicate derivation from a tectonically active but distal source (e.g. Haines et al., 2001). From the observations made above it is clear that the EPGGT did not form a significant source of detritus for the upper part of the formation.

Various studies have observed that turbidity currents typically flow parallel to the long axis of elongate confined basins, such as the Mosquito Creek Basin, parallel to basin-controlling normal faults (e.g. Kneller et al., 1991; Flöttmann et al., 1998; Haines et al., 2001). The long axis of the Mosquito Creek Basin trends in a northeasterly to easterly direction; thus, the source of the material in the basin is likely to be an unknown terrane to the east (Fig. 1), or under the Hamersley Basin to the southwest, west of the Sylvania Inlier, which is the largest granite–greenstone terrane exposed in the southeastern Pilbara Craton (Tyler, 1990, 1991).

Conclusions

Geochronology and detailed mapping have identified the following characteristics of the Mosquito Creek Basin:

- the Mosquito Creek Formation is likely to have an age between 2926 and 2905 Ma;
- the basal part of the Mosquito Creek Formation has a provenance that includes the EPGGT;
- the WPGGT and EPGGT are not the main provenances for the upper part of the Mosquito Creek Formation; and

- the provenance for the turbiditic upper part of the Mosquito Creek Formation is either to the southwest towards the Sylvania Inlier, or the east under the Hamersley Basin (Fig. 1).

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