
Hydrocarbon generation and expulsion from the three mature Ordovician source intervals — the lower A1 (Nambert–Willara Formation), lower A2 (lower Goldwyer Formation) and upper A2 (upper Goldwyer Formation) — is probably limited to the Dampier–Jurgurra Terrace, outer Barwire Terrace, and northern Fitzroy Trough. Peak generation of the oldest, lower A1 source on these terraces (Fig. 11a) probably occurred during the Devonian–Early Carboniferous depositional cycle (before the Meda Transpression), whereas peak generation in the Fitzroy Trough occurred in the Middle Ordovician (before the Prices Creek Movement). This interval probably did not generate large amounts of oil on the Broome Platform during either the Ordovician–Silurian or subsequent depositional cycles. Peak generation of the lower A2 source interval probably occurred during the Devonian–Early Carboniferous (before the Meda Transpression) on the Jurgurra Terrace, and during the Triassic (before the Fitzroy Transpression), whereas peak generation in the Fitzroy Trough occurred during the Early Carboniferous (before the Meda Transpression) on the Dampier–Jurgurra and outer Barbwire Terraces (Fig. 11c). Foster et al. (1986: APEA Journal, 20(1), 142–155) estimated that under optimal maturation conditions this interval has the potential to generate 61 x 10^9 barrels of liquid hydrocarbons on the Barwire Terrace alone.

The newly identified Late Ordovician lower B1 (Bongabini Formation) source interval is immature in the Admiral Bay Fault Zone, the only area where it has been identified. It probably requires burial of about 2000 m to generate hydrocarbons in this area. Local maturation of this source by migrating hydrothermal fluids may explain the occurrence of numerous oil shows in this area, including the oil recovered in Leo 1 and Great Sandy 1 wells.

**Upper Palaeozoic source intervals**

Oil (and minor gas) generation and expulsion from the Givetian–Frasnian lower D source interval (Gogo Formation and equivalent restricted carbonates facies) occurred throughout the Fitzroy Trough in the Late Devonian–Early Carboniferous, before the Meda Transpression. Significant generation also occurred on the Laurel Downs and Jurgurra Terraces at this time, and again during the Permian–Triassic before the Fitzroy Transpression. Peak generation on the Lennard Shelf and Dampier–Barbwire Terraces also occurred during the Permian–Triassic.

Oil and gas generation from the Tournaisian lower F source interval (lower Laurel Formation) occurred in the southern and central Fitzroy Trough during the Triassic, and during the Triassic immediately before the Meda Transpression. Generation probably also commenced on the Jurgurra Terrace at that time. Peak generation in the northern Fitzroy Trough and Jurgurra Terrace possibly occurred in the Triassic, immediately before the Fitzroy Transpression. Thus the large anticlinal structures formed during the Fitzroy Transpression, which have previously been regarded as prospective traps, are unlikely to be charged by this source.

**Key hydrocarbon-preservation factors identified by the study**

Geohistory analyses have provided new insights into the distribution, structural partitioning, original kerogen type, and timing of hydrocarbon generation and expulsion of these source intervals. The work has highlighted the need for more reliable maturity parameters throughout the basin succession, especially within the Ordovician–Silurian section. The study suggests that the key critical factor yet to be systematically evaluated for successful exploration of the basin is scale integrity.

Details of this geohistory analysis were recently published by Kennard et al. (1994: AGSO Record 1994/67, 243 pp.).

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**High-resolution geochronology of Palaeoproterozoic layered mafic-ultramafic intrusions in the East Kimberley**

The Palaeoproterozoic layered mafic-ultramafic intrusions in the East Kimberley have attracted considerable exploration interest for occurrences of platinum-group elements (PGEs), Cr, Ni, Cu, Co, and Au. However, there have been few attempts to identify different phases of mafic-ultramafic magmatism and associated mineralisation on a regional scale. High precision U–Pb ages of fractionated anorthositic and gabbroic cumulates reported here indicate that the prospective Panton, Springvale, and Toby layered intrusions were emplaced over a short time period at 1855–1857 Ma, and that the large McIntosh intrusion was emplaced at 1830 ± 3 Ma. The 1855–Ma layered intrusions are broadly coeval with the felsic Whitewater Volcanics and associated granites of the Bow bathiolith (~1850–1860 Ma).

A recent geochronological study of the Palaeoproterozoic of the East Kimberley has obtained ages for zircons from cumulate rocks, and from zirconium dated during emplacement of another layered intrusion. This study is part of the Kimberley–Arunta National Geoscience Mapping Project accord project being carried out by AGSO and the Geological Survey of Western Australia.

The layered mafic-ultramafic intrusions in the East Kimberley were collectively grouped by Dow & Gemmell (1969: BMR Bulletin 106) into the Alice Downs Ultramafics and the McIntosh Gabbro. However, contact relations with country rocks, degrees of fractionation, styles and intensities of deformation, and types of associated mineralisation indicate that these intrusions are of different types and ages. Field relations and U–Pb geochronological data show that the intrusions can be assigned to seven main groups, at least three of which appear to be coeval (Fig. 12).

Fractionated anorthosites and high-Zr-bearing gabbros (containing up to 140 ppm Zr) were sampled from five potentially economic layered intrusions for U–Pb zircon dating (using the SHRIMP II ion-microprobe located in the Research School of Earth Sciences, Australian National University). The Panton and Sally Malay layered mafic-ultramafic intrusions contain the largest resources of PGE–Cr–Ni–Cu–Au and Ni–Cu–Co, respectively, in the East Kimberley. The Springvale and Toby mafic intrusions host minor amounts of chrome, and the large McIntosh mafic intrusion has potential for Ti–V and Au resources (Houtson & Tyler 1993: AGSO Research Newsletter 18, 8–9). Locations of intrusions dated are shown in fig. 10 of Houtson 1993: AGSO Research Newsletter, 19, 9–10).

**Panton intrusion (group I)**

The Panton mafic-ultramafic intrusion is a synclinally folded body that consists of a lower ultramafic series, 650 m thick, of olivine and chromite cumulates, and an overlying gabbroic series, 900 m thick, of gabbro, norite, anorthosite, and ferrogabbro. On its southern margin the Panton body intrudes gneissic granite dated at 1863 ± 3 Ma (Rose Bore Granite in the Panton River) and older metasediments. Zircons from a mottled anorthosite in the upper part of the gabbroic series in the Panton intrusion are somewhat older, quartz euhedral grains that have high U (2000–5000 ppm) and very high Th/U. They form a single concordant data set indicating a U–Pb age of 1856 ± 2 Ma, interpreted as the time of igneous crystallisation for the Panton intrusion.

**Springvale intrusion (group II)**

The Springvale intrusion is a moderately dipping mafic sheet ~2 km thick comprising olivine gabbro, gabbro-norite, troctolite, and anorthosite. A population of clear subhedral to shapeless zircons was extracted from a mottled anorthosite hosting disseminated chromite in the northwestern part of the intrusion. These zircons have only moderate U contents (230–1500 ppm) but higher Th/U than the Panton zircon suite. The zircon U–Pb data set is concordant, and indicates an igneous crystallisation age of 1857 ± 2 Ma for the Springvale intrusion.
The Lakefield Basin

A newly named Permian basin in far north Queensland

The eastern margin of the Lakefield Basin is apparent from the distribution of Permian (~273 Ma) rocks, and older rocks (Hodgkinson Formation and granite) of the Hodgkinson Province, in coal-search drillholes and in outcrop; and from the interpreted position of the subcropping Palmerville Fault (Fig. 14). South of the Laura Basin, the Palmerville Fault crops out as a major lineament that separates Proterozoic metamorphic rocks in the west from Palaeozoic Hodgkinson Province rocks in the east. Locally divergent branches of this fault also incorporate as a sliver one of two Permian formations (Lakefield Basin correlatives: Little River Coal Measures and Normandy Formation) that crop out near the southern margin of the Laura Basin (Fig. 14). Fault parallel outcrops of the Chillagoe Formation adjacent to the Palmerville Fault and Little River Coal Measures outcrop coincident with narrow intense positive magnetic highs. Magnetic highs with similar wavelengths traceable northwards as far as the coast at about longitude 144°20′E in Princess Charlotte Bay (Fig. 14) reflect the Chillagoe Formation subcrops beneath the Laura Basin.

Again in the Hodgkinson Province, gravity lows correlate in areas of outcrop with mainly S-type Permo-Carboniferous granitoids. Farther north, in the Laura Basin area, similar gravity lows are abruptly truncated on the eastern edge of the narrow belt of inferred Chillagoe Formation subcrops beneath the Laura Basin (Fig. 14).

The foregoing observations suggest that the Palmerville Fault and rocks outcropping along the western margin of the Hodgkinson Province subcrop beneath the Laura Basin with a strike just east of north, and that the eastern margin of the Lakefield Basin has an apparent boundary parallel to the Chillagoe subcrop.

Conclusions

The geochronological data for the layered mafic–ultramafic bodies of groups I–III show that they were emplaced over a brief period around 1855 Ma, 25 Ma before the group VII McIntosh intrusion was emplaced. The older layered intrusions are therefore contemporaries of some of the felsic rocks of the Bow baltholith and Whitewater Volcanics. Together, this mafic and felsic magma (~1850–1860 Ma) represents a major pulse of heat into the Earth’s crust during the development of the Halls Creek Orogen.

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