# The Kombolgie Subgroup — a new look at an old 'formation'

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**Rocks that we assign to the Kombolgie Subgroup (Fig. 26) underlie the Arnhem Land Plateau, and form the Arnhem Land escarpment in Kakadu National Park. Named the Kombolgie Formation during the first systematic regional geological mapping of the Pine Creek region in the 1950s (synthesised by Walpole et al. 1968: BMR [AGSO] Bulletin 82), these rocks were mapped in greater detail during the reappraisal of the Katherine–Darwin region in the 1970s to 1980s by BMR (AGSO's predecessor; e.g., Needham 1988: BMR [AGSO] Bulletin 224). More recently, the unit has been re-examined during joint NTGS (Northern Territory Geological Survey)–AGSO remapping of Arnhem Land and adjacent areas under the auspices of the National Geoscience Mapping Accord (NGMA). Stratigraphic, sedimentological, and geochronological studies have shed new light on these rocks. The unit now has better defined age constraints, and its nomenclature has been revised to reflect some of the complexities of its stratigraphic evolution. As a result, the former *Kombolgie Formation* has been elevated in rank to the *Kombolgie Subgroup*.**

## Stratigraphy and nomenclature — new results

The Kombolgie Subgroup, a quartz sandstone–conglomerate–basalt unit forming the basal part of the Palaeoproterozoic Katherine River Group, is the oldest component of the northwest McArthur Basin. This unit has been progressively more rigorously defined as new information on lithologies and relationships became clear (Fig. 27).

The initial systematic work of Walpole (1962: 'Mount Evelyn, NT — 1:250 000 Geological Series, SD/53–5', BMR [AGSO], Canberra) and Randal (1963: 'Katherine, NT — 1:250 000 Geological Series, SD/53–9', BMR [AGSO], Canberra) was varied in only a minor way by Roberts & Plumb (1965: 'Mount Marumba, NT — 1:250 000 Geological Series, SD/53–6', BMR [AGSO], Canberra), who assigned glauconitic sandstones at the top of the 'Kombolgie Formation' to a separate formation — the McKay Sandstone.

Major advances in understanding the stratigraphy of this northern marginal part of the McArthur Basin were made by Needham & Stuart-Smith (1985: Australian Journal of Earth Sciences, 32, 219–230), particularly with regard to the relationships within a complex of coarse clastics and volcanics underlying the Kombolgie unit; Walpole et al. (1968: op. cit.) had included some components of these in the 'Kombolgie Formation'. Recognising an unconformable relationship, Needham & Stuart-Smith (1985) assigned the older rocks to two newly defined groups — the Edith River and El Sherana Groups. They also introduced the widely used informal labels, $Phk_1$ and $Phk_2$, for the lower and upper Kombolgie sandstones, respectively; identified a local unconformity between the Nungbalgarri Volcanic Member and $Phk_2$; and mapped $Phk_2$ overlapping $Phk_1$ onto rocks of the Pine Creek Inlier.

In remapping the Milingimbi Sheet area (SD53–2), Carson et al. (in prep.: 1:250 000 Geological Map Series explanatory notes, NTGS–AGSO) have formalised a new nomenclature. They have raised the 'Kombolgie Formation' to Subgroup status; formally named and redesignated as formations the informal members, $Phk_1$ and $Phk_2$; redesignated the Nungbalgarri member as a formation; and incorporated the McKay Sandstone into the Kombolgie Subgroup (Fig. 27). Regional unconformities apparently truncate both the Nungbalgarri Volcanics and Gilruth Volcanic Member.

This nomenclature has been extended southwards (e.g., Sweet et al. 1999: 'Mount Marumba SD53–6 — 1:250 000 Geological Map Series explanatory notes', NTGS–AGSO), and is applicable throughout the whole outcrop belt of the Kombolgie Subgroup.

## Age

In the first systematic isotopic geochronology in the McArthur Basin, the Katherine River Group (KRG), of which the Kombolgie Subgroup is a part, was bracketed between 1790 and 1520 Ma on the basis of K–Ar dating by McDougall et al.(1965: Journal of the Geological Society of Australia, 12, 67–90). The first dating to focus on the Kombolgie unit (Page et al. 1980: in 'Uranium in the Pine Creek Geosyncline', International Atomic Energy Agency, Vienna, 39–68) defined a lower age limit of 1688 Ma (Rb–Sr age of the Oenpelli Dolerite, which was interpreted as being overlain unconformably by the Kombolgie unit) and an upper limit of 1648 Ma (the minimum age for the then 'Nungbalgarri Volcanic Member' of the 'Kombolgie Formation').

Since then, single-crystal U–Pb SHRIMP dating of zircons from the Plum Tree Creek Volcanics, which are clearly overlain unconformably by the Kombolgie Subgroup, has yielded an age of 1822 Ma (R.W. Page, quoted in Kruse et al. 1994: 'Katherine SD53–9 — 1:250 000 Geological Map Series explanatory notes', NTGS–AGSO). Three separate SHRIMP zircon ages provide a minimum age for the Kombolgie Subgroup:

- the West Branch Volcanics, at the top of the KRG and some 1000 m stratigraphically above the Kombolgie Subgroup in the Katherine area, are 1705–1712 Ma old (Page, in Kruse et al. 1994: op. cit.);
- the Jimbu Microgranite (Rawlings & Page 1999: Precambrian Research, 94(3–4), 225–250), which intrudes the upper KRG, has been dated at 1720 Ma, thus providing a reliable minimum age for the Kombolgie Subgroup; and
- a slightly tighter constraint on the minimum age is based on the correlation of the McCaw Formation, some 500 m stratigraphically higher in the upper KRG, with the Wollogorang Formation in the Tawallah Group (southern McArthur Basin); felsic volcanics in the lower Wollogorang Formation have been reliably dated at $1729 \pm 4$ and $1730 \pm 3$ Ma by Jackson et al. (1997: AGSO Research Newsletter 26, 20–22).

The age of the Kombolgie Subgroup is thus firmly constrained between 1822 and 1720 Ma — ~100 Ma (and more) older than previously believed — and cannot be an equivalent of the McArthur Group (as asserted by Plumb 1985: Precambrian Research, 29, 303–329), which is firmly established as being younger than about 1700 Ma (Page & Sweet 1998: Australian Journal of Earth Sciences, 45, 219–232).

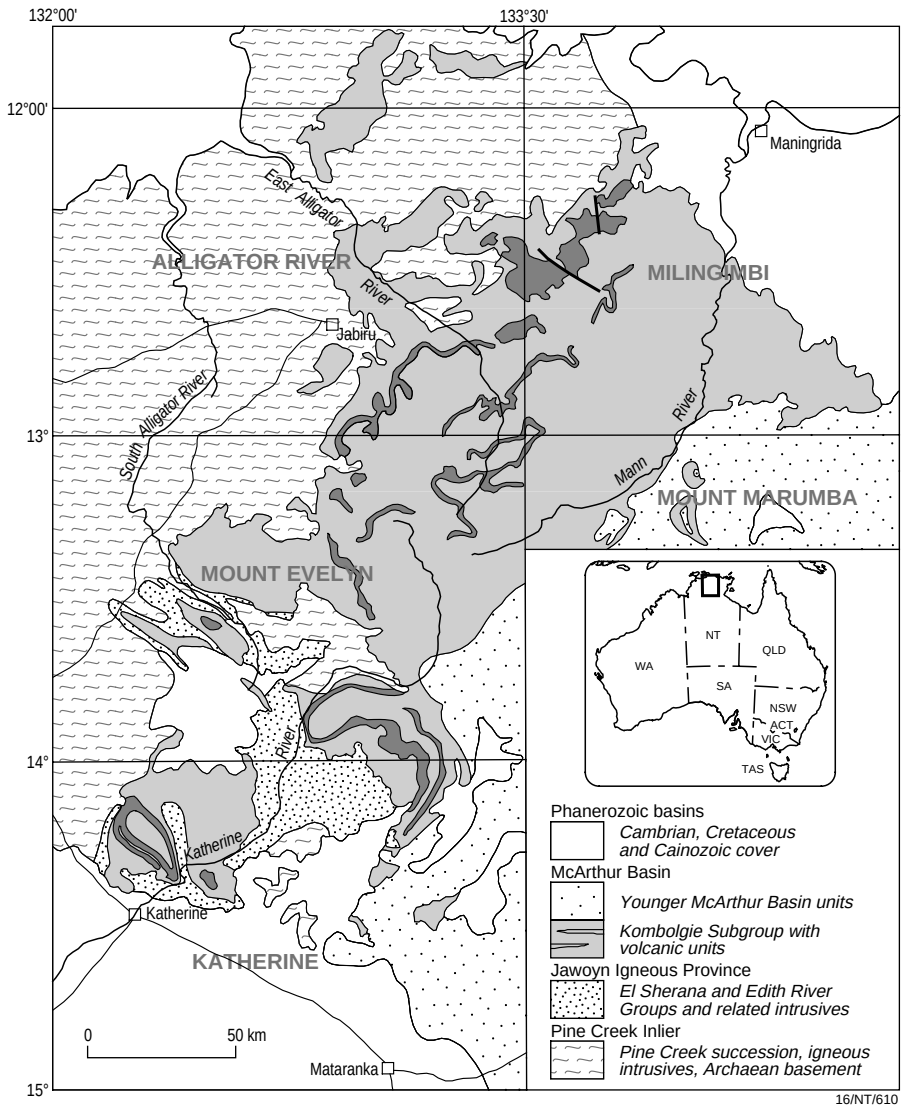


**Fig. 26. Location map for outcrops of the Kombolgie Subgroup.**

Since the Subgroup forms the basal part of the KRG, its age is probably closer to 1800 Ma than to the upper limit of ~1720 Ma.

## Sedimentology and environmental studies

Walpole et al. (1968: op. cit.) regarded the Kombolgie unit as being deposited under 'shelf conditions' (i.e., in a marine environment), but subsequent workers generally interpreted the depositional environment as fluvial (e.g., Needham 1984: 'Alligator River, SD/53–1 — 1:250 000 Geological Series explanatory notes', BMR [AGSO], Canberra). This interpretation is largely based on the general aspect of the sediments — strongly cross-bedded pebbly sandstone — and on a sedimentological study of the (now) Mamadawerre Sandstone by Ojakangas (1979: US Department of Energy report GJBX–173(79), 1–37), who concluded that the rocks were the product of a braided fluvial system with mainly east to southeast sediment transport across a broad braid plain sourced from the west to northwest.

Our work has shown significant departures from this model. For example, in the Katherine 1:250 000 Sheet area, Kruse et al. (1994: op. cit.) noted a strong south to southwest component in the upper part of the Subgroup, indicating transport from the northeast, and a similar pattern is evident in Mount Marumba (Sweet et al. 1999: op. cit.). In Milingimbi, Carson et al. (in prep.: op. cit.) have documented west to southwesterly sediment transport in the Mamadawerre Sandstone, and mainly southerly transport in younger parts of the Subgroup. Thin intervals of thinner-bedded sandstone with an abundance of symmetrical ripple marks in the younger parts in Milingimbi may be marine sands, as they display bipolar (SW–NE) currents, but Carson et al. (in prep.) interpret these intervals as possibly the product of distal sandy flood plains subject to sheet-flooding.

## Tectonic setting

The Mamadawerre Sandstone and Nungbalgarri Volcanics (and equivalent volcanics; Fig. 27) vary markedly in thickness, and appear to be limited above by a regional unconformity. In the central southern Mount Evelyn 1:250 000 Sheet area (Stuart-Smith et al. 1988: 'Stow Region, Northern Territory — 1:100 000 Geological Map Commentary', BMR [AGSO], Canberra), sedimentation of these units apparently was fault-controlled, for they thin rapidly from around 1500 m to zero over a few kilometres. It may be no coincidence that local depositional basins in which these units accumulated are closely related spatially to coarse clastic rocks and volcanics of the El Sherana and Edith River Groups, and hence may be closer in age to these groups. The younger components of the Subgroup, the Gumarrirnbang Sandstone and younger units, show no such abrupt thickness changes, and appear to blanket the older packages. The implications of this are that a phase of extension and local basin formation during El Sherana–Edith River Group–Mamadawerre Sandstone–Nungbalgarri Volcanics time preceded the development of a broader sag basin during the remainder of Kombolgie Subgroup time, and that the unconformity at the top of the Edith River Group represents a time break of only a few million years.

## Conclusions

The Kombolgie Subgroup is an appropriate name for the collection of formations and members previously referred to as the 'Kombolgie Formation'. The Subgroup is constrained in age between 1822 Ma and probably 1730 Ma (certainly >1720 Ma), and is presumed to occupy only an earlier portion of that time interval. The recognition of a regional unconformity above the Nungbalgarri Volcanics and its equivalents offers scope for interpreting the older parts of the Subgroup as products of an extensional regime 1800 Ma or more ago, and the younger parts as sag basin

deposits several to tens of millions of years younger. The lower parts were deposited in a mainly braided stream environment punctuated by brief intervals of marine deposition. Marine conditions predominated only at the top (McKay Sandstone), but thin intervals in the Gumarrirnbang and Marlgowa Sandstones may also be marine.

Whereas the stratigraphy of the Subgroup is now moderately well understood, it could be improved by a systematic reassessment of stratigraphic thickness variations. The palaeogeography during deposition is still poorly understood, and could be enhanced by a systematic palaeocurrent and facies study of the Subgroup. Much remains to be done in improving our understanding of the tectonic setting of the Subgroup, which appears to include elements of a lower extensional basin and an upper sag basin. Further studies could yield dividends both in terms of our understanding of the provenance of the sands, and of the tectonic setting into which these sands were deposited. An understanding of these features has not only intrinsic interest in terms of understanding the landscape features of Kakadu and Nitmiluk National Parks but would have practical application in minerals exploration in areas outside the parks.

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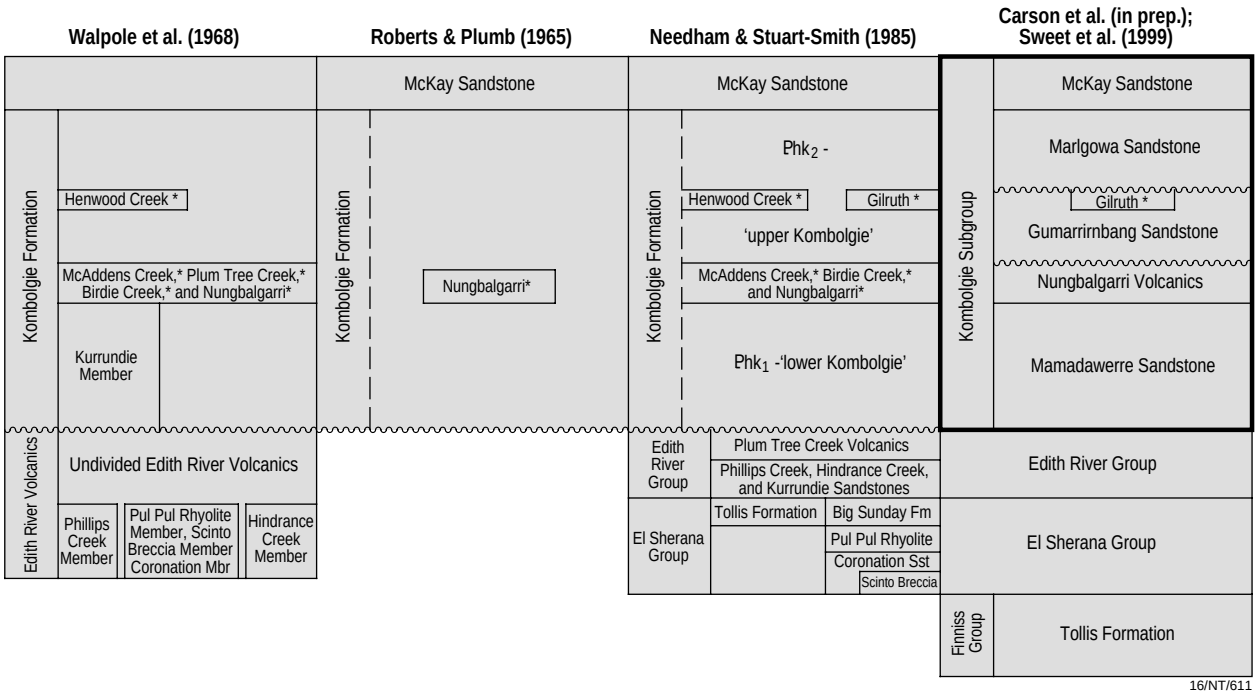


**Fig. 27. Past (first three columns) and present (last column) nomenclature of the Kombolgie unit and adjacent formations/members. Full names of units with an * is ... Volcanic Member. Note that the names McAddens Creek and Birdie Creek Volcanic Members are still applied to units in the Mount Evelyn and Katherine 1:250 000 Sheet areas.**