

NEW RADIOMETRIC AGES FOR TRIASSIC FLORAS OF SOUTHEAST GONDWANA

GREGORY J. RETALLACK¹, PAUL R. RENNE², and DAVID L. KIMBROUGH³

¹ Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403

² Institute of Human Origins, 2453 Ridge Road, Berkeley, California 94709

³ Department of Geological Sciences San Diego State University, San Diego, California 92182

ABSTRACT: New laser-heating ⁴⁰Ar/³⁹Ar radiometric ages have been obtained for volcanic rocks intercalated with sediments yielding megafossil plants, and in one case also marine fossils, in Australia and New Zealand. Plagioclase from the Dalmally Basalt Member of the Bardool Conglomerate in the southern Clarence-Moreton Basin of New South Wales has yielded an age of 237.0 ± 0.4 Ma (2 error). Biotites from an upper Etalian tuff in the Hokonui Hills of Southland, New Zealand, have yielded an age of 242.8 ± 0.6 Ma. The biostratigraphic transition from the *Dicroidium zuberi* to *D. odontopteroides* zones was before these ages, as was the appearance in New Zealand of the bivalve *Daonella* which defines the base of the Etalian stage. Our new age determinations are compatible with a late Anisian appearance at roughly 244 Ma of *D. odontopteroides* and *Daonella* in southeast Gondwana and with a recently proposed Permo-Triassic boundary at ca. 251 Ma.

INTRODUCTION

The distinctive Permian and Triassic fossil floras and faunas of the Gondwana continents were instrumental in initiating inquiry into continental drift, culminating in what is arguably the greatest geological discovery of the twentieth century, the theory of plate tectonics. The very peculiarity of Gondwanan fossils however, has made difficult their correlation with international geological time scales based on Tethyan marine ammonoids. A variety of local biostratigraphic schemes have been constructed for Gondwana (Anderson and Anderson, 1983). For example, the succession of Triassic fossil floras in New South Wales, Australia has been used as a basis for a biostratigraphy of megafossil plants that can be applied widely in southeastern Gondwana, including Australia, New Zealand and Antarctica (Retallack, 1977, 1978). Even in marine rocks of New Zealand, which have yielded ammonoids and bivalves that can be correlated internationally, a local sequence of chronostratigraphic stages has been established (J.D. Campbell, 1985). This paper is a contribution to the radiometric dating of these local biostratigraphic and chronostratigraphic schemes of New Zealand, Australia and Antarctica.

METHODS

Radiometric age determinations were performed on separates (~20 mg) of optically-clear, unaltered plagioclase from the Dalmally Basalt and 2 individual grains of biotite from upper Etalian tuff. Plagioclase samples were rinsed in dilute hydrochloric and hydrofluoric acids. Biotites were ultrasonically cleaned in distilled water. Samples were incrementally heated using the facilities and procedures outlined by Renne and Basu (1991). Fish Canyon sanidine, with a reference age of 27.84 Ma, was used as a neutron fluence monitor.

DALMALLY BASALT MEMBER, NYMBOIDA, NEW SOUTH WALES

The Dalmally Basalt is a member of the Bardool Conglomerate in the southern Clarence-Moreton Basin of northeastern New South Wales, Australia (Retallack et al., 1977). Samples of the basalt (University of New England, Armidale, R34382) were collected by Gregory Retallack, Hayden Butler and Rodney Gould from the bank of Copes Creek, 4 km southwest of Nymboida Post Office (grid reference 808877 on Nymboida 1:63,360 map). Here the basalt is 15 m thick, dipping to the northeast and concordant with both enclosing fluvial conglomerates and the stratigraphically higher Copes Creek Tuff (McElroy, 1963). The basalt has a variety of features characteristic of a lava flow: a chilled base, coarsely crystalline central portion and a vesicular and locally scoriaceous top (Retallack et al., 1977). The reason this basalt was chosen for dating is because it lies stratigraphically between two diverse yet identical megafossil floras, that can be assigned to the *Dicroidium odontopteroides* opeelzone and *Dicroidium odontopteroides* ecostratigraphic unit (Retallack, 1977, 1978).

Our new age determination for plagioclase of the Dalmally Basalt is 237.0 ± 0.4 Ma (2 σ error: Fig. 1a). The rock used for dating was part of the same sample previously dated by D.C. Green of the University of Queensland using the ⁴⁰K/⁴⁰Ar method on plagioclase, with the very different result of 211 ± 5 Ma (Retallack and others, 1977). Even when corrected to modern constants using conversion factors of Dalrymple (1979), this becomes only 216 ± 5 Ma. This younger estimate may have been the result of argon leakage, because it makes no sense in the context of the radiometric calibration of the Triassic time scale (Harland et al., 1990). Estimates of 211-216 Ma fall within the Norian (Figure 2), whereas associated fossil plants indicated roughly

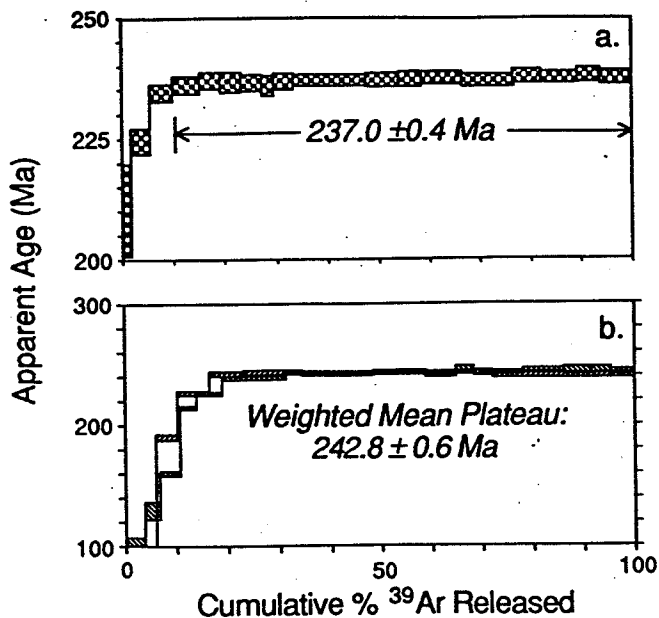


FIGURE 1. Apparent age spectra, showing apparent age as a function of cumulative fraction ^{39}Ar released from samples of (a) plagioclase of the Dalmally Basalt of New South Wales and (b) biotites from an upper Etalian tuff of New Zealand. Vertical width of each increment corresponds to 2σ uncertainty in apparent age.

Ladinian or Anisian age, now supported by our new estimate of 237 Ma.

UPPER ETALIAN TUFF, DIPTON, NEW ZEALAND

Samples of a thick crystal-vitric tuff (Otago University specimen 49179) were collected by David Kimbrough on the ridge south of the McClean farmhouse, in the Hokonui Hills, 4.7 km north of Dipton, Southland, New Zealand (NZ 1:63,360 map S160 grid reference 382674). This thick, dark, heulandite tuff is within the Taringatura Group, less than 100 m stratigraphically below the mapped base of the Kaihikuan and some 1600 m above the base of the Etalian in the underlying North Range Group (Boles, 1974). The Etalian Stage is a chronostratigraphic unit defined by the local appearance of the cosmopolitan marine bivalve *Daonella apteryx*, and is below the Kaihikuan Stage which is defined by the appearance of the endemic brachiopod *Alipunctifera kaihikuana* (J.D. Campbell, 1985). The Kaihikuan stage is represented in this area by such well known localities as Caroline Cutting (J.D. Campbell, 1980), and the Etalian by sporadic occurrences of *Daonella* (Retallack, 1985). Also found in this area are plant fossils in the North Peak Formation, which underlies the Etalian Stag Siltstone and overlies the Malakovian Crosshill Gully Siltstone of the North Range Group. Especially notable is the occurrence of reproductive structures similar to *Umkomasia granulata* ("*Pilophorosperma* sp. cf. *P. granulata*" of Retallack, 1985, following Retallack and Dilcher, 1988). This fertile fragment is an indication that the associated foliage fragments of *Dicroidium* include *D. odontopteroides*, a biostratigraphically important seed fern (Retallack, 1977). Also found

in the North Peak Formation is *Pachydermophyllum*, an indicator seed fern for the *Pachydermophylletum* ecostratigraphic unit, which is interpreted as a Triassic mangal (Retallack, 1985, 1987). Common in Etalian rocks of New Zealand beyond the Hokonui Hills are *Taeniopteris lentriculiforme* and *Heidiphyllum elongatum*, which are conspicuous elements of other ecostratigraphic unit found in both New Zealand and Australia (Retallack, 1977, 1978, 1985).

Two individual grains of biotite from the upper Etalian tuff were incrementally heated with the laser. Both yielded discordant age spectra that gave indistinguishable plateaus of 242.3 ± 0.8 and 243.4 ± 0.8 (2σ errors: Fig. 1b). The weighted mean of the two plateau ages is 242.8 ± 0.6 Ma. Discordance of the biotite's spectra may be due to either episodic loss of argon, or (more likely) the influence of an interlayer secondary phase such as vermiculite (Renne et al., 1990). In either case the integrity of the plateau age is intact.

These age determinations are supported by less precise U/Pb age determinations from low-U (200 ppm) zircons separated from this same tuff by David Kimbrough. There are difficulties in interpreting the U/Pb data due to inheritance from Proterozoic rocks combined with slight amounts of Pb loss (Kimbrough and Mattinson, 1984; Harland et al., 1990, table 4.2). The U/Pb ages range from 236.8 ± 5 to 243.1 ± 5 , with the latter result from a slightly discordant fine-grained fraction leached with HF. In addition, zircons from a crystal tuff in the well known Kaihikuan beds at Parks Cutting on the coast near Balclutha (J.D. Campbell, 1980) yielded a concordant U/Pb age determination of 235.8 ± 5 Ma. These data lend support to the more precise argon-plateau age estimates reported here.

CONCLUSIONS

These new radiometric age determinations clarify confusion created by an inaccurate earlier determination and more firmly constrain a number of biostratigraphically important events (Fig. 2).

The appearance of *Dicroidium odontopteroides* in southeastern Gondwana defines the base of the *D. odontopteroides* zone (Retallack, 1977) and is now known to be earlier than 237 Ma from our new date on the Dalmally Basalt and before 243 Ma from our new date for the upper Etalian tuff. How much before 243 Ma is uncertain. The considerable thickness (1.6 km) of Etalian sediments containing at least two distinctive ammonoid faunas below the tuff is suggestive of a length of time of the order of millions of years. An appearance of *Dicroidium odontopteroides* in southeast Gondwana at roughly 244 Ma would be consistent with our new age determinations.

The new radiometric ages also offer constraints for the time of appearance of plant associations thought to reflect local paleoecological variation in vegetation (Retallack, 1977, 1978). It is likely that Middle and Late Triassic fossil plant associations such as *Pachydermophylletum* mangroves, *Taeniopteretum lentriculiformis* freshwater lagoonal woodland, *Heidiphyllum* streamside gallery woodland and *Dicroidietum coriacei* dry woodlands also range back in age some 244 Ma.

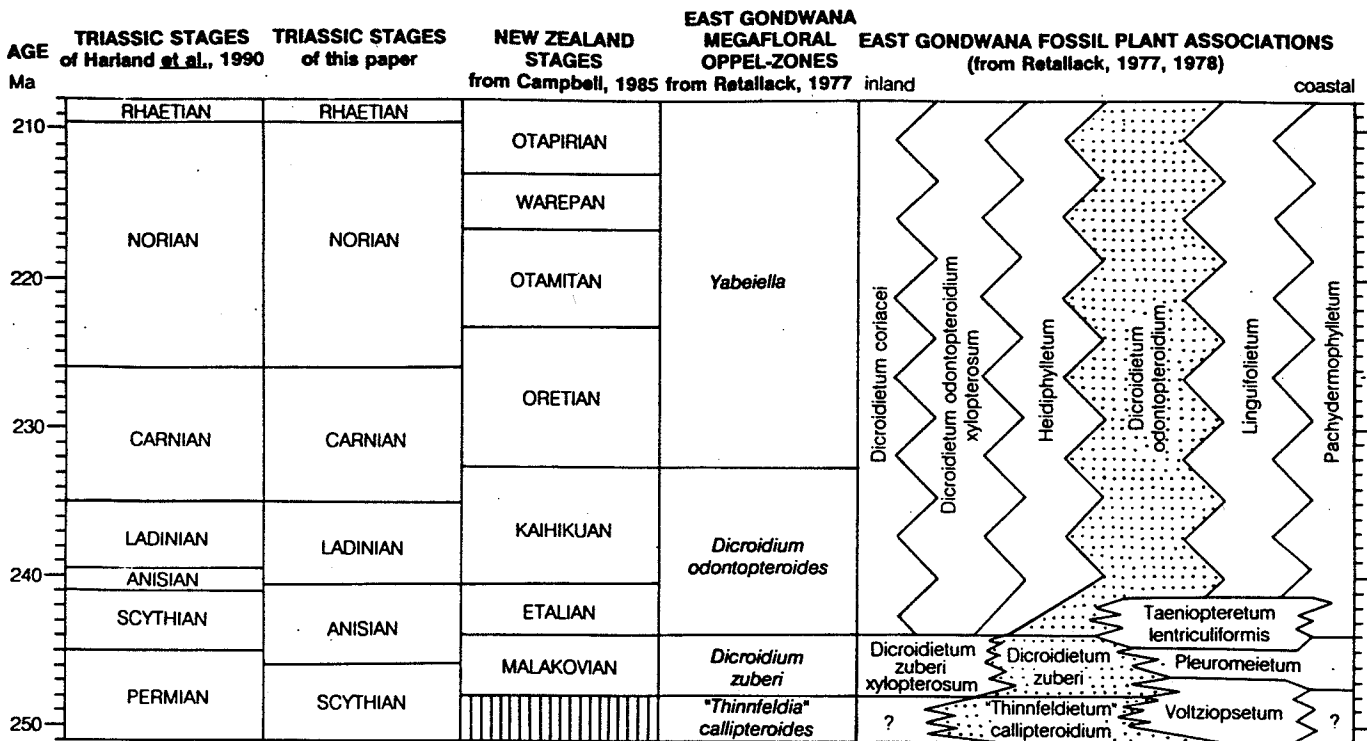


FIGURE 2. A correlation chart for Triassic stages of New Zealand and megafloal zones and ecostratigraphic units for southeast Gondwana, showing suggested revision of the Middle and Early Triassic time scale of Harland et al. (1990). Stippled ecostratigraphic units are interpreted as former mesophytic forests and are the basis for the floral biostratigraphy.

In North America, *Daonella* appears in the later part of the middle Anisian with the commonly associated ammonite *Amphipopanoceras* in the earlier part of the late Anisian (Silberling and Tozer, 1968; Tozer, 1982). Our new radiometric age determinations place a youngest limit of 243 Ma on the first appearance of these biostratigraphically important marine fossils in New Zealand. Like *Dicrodium odontopteroides*, the cosmopolitan marine fossils *Daonella* and *Amphipopanoceras* probably appeared in New Zealand at roughly 244 Ma.

Our new estimate of 244 Ma for these biostratigraphic events within the early part of the Middle Triassic is at variance with the time scale of Harland et al. (1989) who place the Permian-Triassic boundary at 245.0 ± 2.5 Ma and a very short Anisian between 239.5 ± 2.5 and 241.2 ± 2.5 Ma. Subsequent age determinations on Chinese tuffs and Siberian traps have extended the age of the Permian-Triassic boundary to 251 Ma (Claoué-Long et al., 1991; I.H. Campbell et al., 1992). The new age determinations reported here are consistent with these recent results extending the Early Triassic and its stages a little further back in time (Fig. 2).

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