Subduction regression of volcanism in New Zealand

IN discussing the origin of Cenozoic calc-alkaline volcanism in northern New Zealand, R. N. Brothers¹ uses a data base of 'time-lines' constructed from 93 selected K-Ar ages. These time-lines are said¹ to "represent the oldest dated rocks, and thus the initiation of volcanism, at eruptive centres throughout the northern North Island". We will show that this is untrue from which it follows that Brothers' time-lines are meaningless.

Brothers' oldest time-lines (in northern Northland) are 21 Myr. There is ample published evidence, however, of andesitic and basaltic tuffs and volcanoclastic sandstones in late Oligocene and earliest Miocene (~26–22 Myr) sedimentary sequences in northern New Zealand (Fig. 1)^{2–4}, which indicates considerably earlier initiation of volcanism within, or closely adjacent to, Northland, although the exact centres have not been determined.

Younger volcanic centres are identifiable; at least eight early Miocene centres are known in northern New Zealand and Brothers has based his time-lines on dated rocks from seven of them. The published stratigraphic data show clearly that eruptions began in the Middle–Upper Otaian Stage (early Miocene, ~23–21 Myr) in at least six centres spread along the length of Northland (North Cape, Whangarei Heads, Waipoua, North Coromandel, Waipoua, Waitakere, Auckland, Thames).

Hukaterere, Waitakere—Fig. 1). These dates are coincident with the oldest K-Ar dates available from a further two centres (Whangaroa¹, Tokatoka¹) which presumably also began erupting about the same time.

Brothers¹ agrees that eruption started at 21 Myr in identified centres in northern Northland, but bases his hypothesis of southward migration of volcanism on a 17-Myr time-line through Waitakere and north Coromandel. The 17-Myr date at Waitakere is taken from pillow lavas interbedded with fossil-dated (mid-Altonian) marine sediments that are high in the volcanic stratigraphic sequence^{5–7} (Fig. 1). The lowest volcanic breccias and lavas exposed at Waitakere are biostratigraphically dated as late Otaian (~21 Myr)⁵, but a number of submarine lahar deposits occurring within flysch around Auckland city are stratigraphically lower than exposed Waitakere rocks⁴. These lahars have features consistent with a western origin³ and indicate initiation of volcanism at Waitakere centre in the early half of the Otaian² (23 Myr). A similar submarine lahar deposit occurs within late Otaian flysch (~21 Myr), 60 km south of Auckland^{4,8}.

Brothers' 17-Myr time-line links Waitakere with dated plutons at north Coromandel⁹ which intrude the local volcanic sequence which in turn conformably overlies Otaian flysch¹⁰. Thus initiation of volcanism here is unlikely to have been later than 20 Myr. South of Brothers' 11-

Myr line (Thames), the base of the eastern volcanic pile in Coromandel Peninsula is not exposed^{11,12} and therefore none of the 'time-lines' between 11 Myr and 2 Myr can date the inception of volcanism in this eastern belt.

We have shown: (1) that the published stratigraphy, available to Brothers, indicates near-contemporaneous initiation of major volcanism in two NW-SE belts in northern North Island in the early Miocene (Otaian, ~23–21 Myr). This volcanism is calc-alkaline in the younger flows and intrusions¹³, and, although the geochemical character of the older volcanoclastics has not been determined, their petrography and geological setting are identical to the younger rocks. (2) The NE-trending 'time-lines', which form the data-base for Brothers' analysis of Cenozoic subduction and volcanism in northern New Zealand, do not record the earliest volcanism at most of the localities shown and are random lines connecting fortuitously-placed K-Ar dates. Therefore a tectonic model based on invalid 'time-lines' is itself invalid.

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Fig. 1 The northern part of North Island, New Zealand, showing location and age of major centres of early Miocene calc-alkaline eruption. Absolute ages have been determined from a combination of K-Ar dates^{1,2} and converted biostratigraphic dates based on the International Time Scale model of Berggren¹⁴ (see right for conversion table from New Zealand stages¹⁵). Generalized columns summarize the stratigraphic evidence for the age of outbreak of volcanism in six areas, with position of biostratigraphic and K-Ar dates shown (North Cape^{16,17}, Whangarei Heads¹⁸, Waipoua^{2,19}, Hukaterere^{2,20}, Waitakere⁵, north Coromandel^{10,21}). New Zealand Stage symbols: Lw = Waitakian, Po = Otaian, Pl = Altonian.

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BROTHERS REPLIES—The comments by Ballance *et al.* reflect the problems of biostratigraphers trying to equate an imprecise time scale with the more exact ages provided by radiometric methods. The time-lines used in my study¹ were