Comment and Reply on “Age constraints on metamorphism and the development of a metamorphic core complex in Fiordland, southern New Zealand”

COMMENT

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Gibson et al. (1988) interpreted the Fiordland region of South Island, New Zealand, as a metamorphic core complex reflecting Mesozoic continental extension tied to Late Cretaceous opening of the Tasman Sea and breakup of Gondwana. In this model, Early Cretaceous granulite facies rocks define a lower plate, everywhere separated by a ductile shear zone from a metamorphically and structurally distinct upper plate of mid-Paleozoic metasedimentary rocks and orthogneisses. 

Unfortunately, little consideration is given to significant geologic differences between Fiordland and the western North American model, or to recent work by other Fiordland investigators that supports a very different view of the geologic evolution of the region. Neither the existence of a regional structural break nor differences in timing and character of metamorphism across its inferred position are supported by recent mapping, petrologic, and geochronologic studies in northern Fiordland. Studies of the granulites here suggest that (1) the protolith synkinematically intruded the mid-Paleozoic sequence (Tuhua Sequence of Gibson et al.), and (2) both granulitic orthogneiss and this country rock subsequently experienced the same polybaric metamorphic history, involving initial low- to medium-pressure metamorphism followed by an increase in pressure attributed to crustal thickening by overthrusting (Bradshaw, 1985; Mattinson et al., 1986; McCulloch et al., 1987). These findings suggest that any break in the metamorphic sequence in the Doubtful Sound area is of local rather than regional significance, and they pose serious problems for the interpretation of Fiordland as a core complex.

The granulites formed within a magmatic arc by a process involving synkinematic recrystallization of anhydrous intrusions; they were stabilized under vapor-absent conditions and record the same pressure and temperature as coeval amphibolite facies assemblages in the country rock in northern Fiordland (Bradshaw, 1985; Mattinson et al., 1986; McCulloch et al., 1987). The granulites have experienced at least three phases of deformation, two of which involved isoclinal folding (Bradshaw, 1985). Any apparent differences in structural complexity between the granulites and amphibolite facies country rock (i.e., “Tuhua sequence”) alluded to by Gibson et al. can be attributed to differences in their response to deformation. There is no evidence to support the claim that these rocks are metamorphically and structurally distinct. Multiply deformed amphibolite facies metasedimentary rocks reported by Wood (1972) in northern Fiordland, and included by Gibson et al. within the so-called Tuhua sequence, record the same metamorphic history and peak pressure conditions as the granulites (Bradshaw, 1985), indicating that they are part of the same structural-metamorphic package. The lower metamorphic pressures (5–9 kbar) cited by Gibson et al. for the metasedimentary sequence in the Doubtful Sound area sharply contrast with the situation in northern Fiordland. Although they may indeed indicate local disruption here by synmetamorphic or postmetamorphic structures (e.g., Doubtful Sound thrust), other alternatives cannot be ruled out, such as disequilibrium, or the possibility that the pressure- and temperature-sensitive equilibria used to estimate pressure were blocked at lower pressures during evolution of the geotherm (e.g., Bradshaw, 1985).

Gibson et al. (1988) maintained that Fiordland metamorphism and structure are primarily a consequence of the Tuhua orogeny (350–380 Ma). However, much of the area shown as Tuhua sequence in Figure 1 of Gibson et al. (1988, p. 405; modified from Mattinson et al., 1986) consists of Mesozoic orthogneiss and undeformed calc-alkaline plutonic rocks, including the Early Cretaceous Darran Complex (Mattinson et al., 1986; McCulloch et al., 1987). Mesozoic orthogneisses have been shown to intrude the metasedimentary sequence in several areas (Ward, 1984; King, 1984; Bradshaw, 1984, 1985). Although Gibson et al. interpreted D1 and D2 structures in central Fiordland to be of mid-Paleozoic age, available data suggest that they are likely to be much younger; these structures affect mineral assemblages in the contact aureole of the Mount George Gabbro (Gibson, 1982a, 1982b), an intrusion that has yielded Early Cretaceous U-Pb zircon ages (D. L. Kimbrough, unpub. data; written commun. to G. M. Gibson, 1984). Furthermore, zoned garnets in pelites of the contact aureole (Gibson, 1979; Bradshaw, 1985) record the same Early Cretaceous pressure increase as the granulites and associated metasediments in northern Fiordland, suggesting that these rocks crystalized during the same event.

Considering the above, it is unlikely that the pre–Early Cretaceous K-Ar hornblende ages obtained by Gibson et al. accurately reflect the minimum age of the deformation. An alternative explanation is that the...
short duration of Early Cretaceous metamorphism was insufficient to re-
homogenize all mineral-isotope systems. Isotopic age data presented by 
Mattinson et al. (1986) and McCulloch et al. (1987), and corroborated by 
Gibson et al., indicate that synkinematic intrusion of the granulite protot-
ith subsequent crustal thickening and related high-pressure metamor-
phism, and final uplift and cooling all occurred within an interval as short 
as 20 m.y., between ~120 and ~100 Ma. Within this short period, the most 
likely driving force of metamorphism was magmatic heating accompa-
nying intrusion of the granulite protolith (Bradshaw, 1985). Magmatic 
heating is consistent with the observation of Gibson et al. of a diminishing 
degree of disturbance of K-Ar mineral systems away from the granulite 
contact. There is no evidence to support the model of Gibson et al. for a 
separate (i.e., post-granulite formation) thermal event related to deep 
crustal extension.

Present understanding of plate-boundary dynamics suggests that both 
tectonic loading and rapid uplift of high-pressure metamorphic terranes 
occurs within convergent regimes with considerable horizontal displace-
ments and large-scale continental underplating. Although uplift within 
such settings may involve significant local extension (Platt, 1986), this 
should not be confused with a purely extensional tectonic environment 
(e.g., divergent plate boundary). Initiation of rifting leading to Late Cre-
taceous opening of the Tasman Sea requires a fundamental and rapid 
change from the earlier magmatic arc-convergent plate-boundary regime 
responsible for widespread Mesozoic magmatism and crustal thickening 
in Fiordland (Mattinson et al., 1986; McCulloch et al., 1987). Fiordland 
metamorphism and structure largely predate this event and thus should 
not be linked with the subsequent extensional regime.

REPLY

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In rejecting our central premise that the western Fiordland ortho-
gneiss and overlying Tuhua Sequence constitute different structural 
entities, Bradshaw and Kimbrough dismiss the mylonites and structural 
brake described by us in Doubtful Sound as being of no more than local 
significance, even though the same sheared contact has been identified 
(Oliver and Coggon, 1979) over a wide area in western Fiordland. We 
reject any suggestion that the Doubtful Sound area is atypical of Fiordland 
as a whole, and we emphasize that these mylonites extend over a vertical 
distance of several hundred metres and affect both the western Fiordland 
orthogneiss and immediately overlying Tuhua Sequence alike; such a zone 
can hardly be considered insignificant.

Data presented in our paper also indicate that mylonitization must 
have closely followed and in some cases overlapped in time with magma 
emplacement, because dike rocks intruded at high angles to the mylonite 
stretching fabric are themselves sheared and metamorphosed (cf. Rehrig, 
1986). It would therefore not be too surprising if intrusive relations are 
sometimes locally preserved in Fiordland. Synkinematic magmatic activity 
has been described in several North American core complexes (Reynolds 
and Rehrig, 1980; Rehrig, 1986), and in itself would seem insufficient 
reason for rejecting our proposition that the western Fiordland orthogneiss 
was primarily emplaced by tectonic processes.

Bradshaw and Kimbrough attribute regional metamorphism in Fiord-
land to magmatic heating accompanying synkinematic intrusion of the 
granulite protolith. In this model the western Fiordland orthogneiss and 
Tuhua Sequence have shared a common polybaric metamorphic history 
since Early Cretaceous time. However, in reaching such a conclusion,
setting for the emplacement of the western Fiordland orthogness, but it also accounts for the contemporaneous development of the rift-related asymmetric basins and their nonmarine sedimentary fill (Pororari Group) in Nelson and Westland. If Fiordland appears different from other core complexes in North America, it is only because it is part of a much more extensive infrastructure which has been dispersed and differentially up-lifted along the mid-Tertiary Alpine fault.

COMBINED REFERENCES CITED

Bradshaw, J.Y., 1984, Contrasting rock belts in northern Fiordland: Metamorphic evidence for a major collision event in western New Zealand: Geological Society of New Zealand Programs and Abstracts.

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