them in the crust suggest a thin or rifted crust (e.g., back-arc rift on continental crust or east African-type continent rift) tectonic environment. (4) The evidence for several episodes of alkaline–peralkaline activity (Lumbers et al. 1990) suggests that the boundary zone of the Central Metasedimentary Belt was the site of prolonged crustal weakness that localized convergent deformation during later thrusting events.

Acknowledgments

We would like to thank C. Gower and S. McCutcheon for their comments on an earlier draft of this discussion.

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Kinematical and rheological evolution of a crustal-scale ductile thrust zone, Central Metasedimentary Belt, Grenville orogen, Ontario:[1] Reply

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Received March 5, 1993
Accepted March 8, 1993

Can. J. Earth Sci. **30**, 649–650 (1993)

We welcome the discussion by R.R. Miller and D.R. Lentz of our study of the Central Metasedimentary Belt boundary thrust zone, referred to herein as the boundary zone. As indicated by the title, our emphasis in the paper concerned the structural aspects of the boundary zone. Our attempt to account for the structural position of the nepheline-bearing rocks within the lithological zonation of the boundary zone by synthrusting metasomatism does not in any way represent a fundamental element in the interpretation we presented for either the structural history or the tectonic setting of the boundary zone. In fact, we devoted only one and a half paragraphs to the subject of the nepheline syenites, that is, a brief literature review and a suggestion that the overlying allochthonous gabbros may have acted as a mechanical barrier to ''nephelinizing fluids.''

The discussers point out that a number of inconsistencies result from a simple syntectonic metasomatic model, and we do not feel that the available petrological data set allows us to offer a convincing riposte. However, we must admit to being somewhat baffled by their contention that we may have confused four orogenic events with magmatic ones, since we did not refer to four orogenic events. More importantly, there are a number of aspects concerning the published data set on

[1]Discussion by R.R. Miller and D.R. Lentz. 1993. Canadian Journal of Earth Sciences, **30**: 647–649.

nepheline syenites and associated rocks used by the discussers to which we would like to draw attention.

The discussers raise an important question, Are the nepheline-bearing rocks associated with the boundary zone of igneous or metasomatic origin? There are both geological and theoretical sides to their argument. First, they correctly point to published interpretations of igneous-textured nepheline-bearing rocks spatially associated with the southwestern part of the boundary zone. Undersaturated mafic plutonic rocks (theralitic canadite of Armstrong and Gittins (1970*a*, 1970*b*) and the olivine-bearing Hadlington gabbro (Grieve and Gittins 1975) are associated with nepheline syenites east of the Glamorgan gabbro (terminology of the discussers). However, they are a local occurrence and not a general feature of the gabbros of the boundary zone. The discussers specifically refer to the work of Appleyard (1974*a*), who studied nepheline syenites in the boundary zone. Appleyard (1974*a*) explicitly considered discrimination of igneous and metasomatic nepheline-bearing rocks in the Central Metasedimentary Belt material to be particularly difficult. In two separate publications, in the same year, he emphasized the metasomatic aspects in one (Appleyard 1974*b*; see also Appleyard and Williams 1981) and the igneous qualities in the other (Appleyard 1974*a*). We note that much of his discussion of the boundary zone material in the latter publication focuses on the same rocks as those in Armstrong and Gittins (1970*a*, 1970*b*) and Grieve and Gittins (1975).

Second, the discussers, citing the theoretical treatment by Anderson and Cermignani (1991), suggest that thermodynamic considerations place severe limitations on metasomatic nephelinization. The latter authors suggested that nephelinization of the type found in the boundary zone (wollastonite absent) would require reaction between plagioclase and Na or NaCl, which they considered unlikely on theoretical or experimental grounds. Nevertheless, we note that Appleyard and Williams (1981) determined, by analysis of natural materials from the boundary zone, that the addition of Na and Cl had accompanied nephelinization and concomitant scapolitization in the Faraday gabbro, near Bancroft. We suggest that an igneous origin for all of the nepheline-bearing gneisses associated with the boundary zone remains unproven.

The discussers suggest that the nepheline-bearing rocks are too old to be syntectonic with respect to events within the boundary zone. They refer to 1.29−1.25 Ga U−Pb zircon ages, which are used to bracket the age of the "nepheline-bearing gneisses" (Lumbers et al. 1990). However, the gneisses in question are not specifically referred to as exhibiting igneous textures, either by Lumbers et al. (1990) or by the discussers. Furthermore, the lower age limit is only inferred, since the *dated* alaskite is not specified as crosscutting the nepheline-bearing gneisses, that is, those inferred to be of igneous origin. Indeed, we note that Appleyard (1974*b*) considered the "igneous" nepheline-bearing rocks to be syntectonic.

The discussers ask why the nepheline-bearing gneisses were not disrupted if the gabbros now represent a boudined, once continuous layer? They then go on to suggest that the gabbros are not nephelinized. The simple answer to the first point is "competence." The gabbros would be boudined because they were stiffer than the enclosing rocks. The similarity of the deformation-induced banding (Davidson 1984; Hanmer 1988) in nepheline-bearing and quartzofeldspathic straight gneisses is indicative of the soft dynamic rheology of the former. Regarding the second point, we note that the study by Appleyard and Williams (1981) examined extensive nephelinization and associated scapolitization preferentially developed in the strongly foliated (sheared?) parts of the Faraday gabbro.

The discussers propose that the nepheline-bearing rocks are of igneous origin, older than ca. 1.25 Ga, and crystallized in thinned or rifted continental crust setting, possibly a back-arc basin. If they are correct, the back-arc basin to which they refer would be the one from which we suggested that the gabbros were thrusted as it closed at ca. 1.19−1.18 Ga. We note that integrated structural and geochronological study of the Central Metasedimentary Belt boundary thrust zone (discussion paper; McEachern and van Breemen, in press) provides the setting for important, probing questions (such as those brought up by the discussers) concerning the tectonic evolution of the Grenville orogen—questions which will only be resolved by strategically targeted, quantitative and isotopic petrological research.

Acknowledgments

We thank Tony Davidson for discussing and commenting on our reply.

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