Reply

Sedimentological changes across the Ordovician–Silurian boundary in Hadeland and their implications for regional patterns of deposition in the Oslo Region: a reply

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Baarli (this issue, pp. 253–255) provides general support for our model of an easterly supply of sediment into the Oslo Region during the latest Ordovician and Rhuddanian. Our block model for the basin is necessarily schematic but, importantly, shows a series of half-grabens with their basement surfaces tilted eastwards. The interplay between fault movement and rate of sediment supply was thus able to produce sea floor topographies which differed from half-graben to half-graben and could show local eastward deepening, but with the overall transport of siliciclastic material into the basin from the east. However, Baarli also provides new and convincing evidence for the derivation of sediment of a new provenance, from the west, during the Aeronian. Our basin model can accommodate this with the continuation of an eastern source and westward dipping palaeoslope in the Hadeland segment of the basin.

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We welcome Baarli's comments on our paper (Braithwaite et al. 1995) and her general support of our proposed easterly source of sediment to the Oslo Region basin during the Rhuddanian. Her detailed criticisms relate only to the uppermost (Aeronian) parts of some of the successions we discussed. In the Hadeland district, where our model was formulated, the faunas of the Lower Silurian Sælabonn Formation are unfortunately restricted, both in diversity and distribution (Heath & Owen 1991, fig. 6). We cannot recognize, even notionally, the Rhuddanian–Aeronian boundary and, although the palaeoecology of these faunas is currently being assessed, we lack the biostratigraphical control required to match the fine scale palaeoenvironmental analyses undertaken by Baarli and her colleagues on equivalent units in Oslo–Asker and Modum. None the less, we can address some of the points raised and also take this opportunity to point out two drafting errors in our paper: on Fig. 2, the base of the Aeronian should be lower (slightly above the base of the Leangen Member of the Solvik Formation in Oslo–Asker) and on the key to the Sælabonn Formation on Fig. 3 the terms 'Unit 1' and 'Unit 3' should be exchanged.

Baarli's comments relate to her comparison of the Aeronian units in Modum and Oslo–Asker. We outlined her work on these successions (Braithwaite et al. 1995, pp. 213–214) but, in largely confining ourselves to areas where we had first-hand knowledge, omitted Modum from our conclusions and from our regional summary diagram. The latter is a schematic block model showing the likely types of structural relationships within the basin and does not define the precise position of any particular fault. To have included the postulated positions of more of the districts of the Oslo Region would have implied far greater precision than we actually have; even the locations of the districts shown are schematic. For the structural reasons which we outlined (Braithwaite et al. 1995, pp. 208–209), the relative positions of, and separation between, the successions in the various districts of the region during the Ordovician and Silurian are far from clear. Differences in structural style, including degree and orientation of deformation and amount of shortening, as well as local evidence for basement faulting, present severe problems to reconstruction and we counsel caution in assuming that the Modum–Asker–Oslo areas lay along a simple west–east transect during the early Palaeozoic. However, taking the points raised by Baarli in turn:

A. The major hiatus in Modum, extending well into the Rhuddanian, does indeed suggest a similarity to Ringerike to the north and contrasts with Oslo–Asker where the gap is restricted to the uppermost Ordovician (Braithwaite et al. 1995, fig. 2), with the base of the Solvik Formation probably representing the late Hirnantian global sea-level rise. For this reason, we suggest that Modum may have been part of the same block within the basin as Ringerike, as shown on our schematic diagram. The western part of this block may have remained emergent during the earliest Silurian while areas to the east were drowned. Note that we portray these blocks as half-grabens, with their basement surfaces tilted eastwards. Thus, at times when fault movement outpaced sedimentation, the palaeoslope may have deepened to the east and hence, as in the Myren Member of the Solvik Formation in Oslo–Asker, the western parts may have been more elevated sites of carbonate deposition while fine-grained siliciclastic sediment dominated to the east. This detrital sediment could not have been derived from, and could not have crossed, the emergent karst surface at Sylling.

B. The previously unpublished information on the petrological composition of the Aeronian Leangen Member of the Solvik Formation provided by Baarli is a welcome addition to the understanding of the basin's history. It suggests, as Baarli indicates, a change in provenance, and the presence of unstable feldspar and chlorite implies that this was a more immature source. However, if this source is seen to be the rising Caledonian nappes to the west, as many have supposed, how is this composition to be explained? A theoretical consideration suggests that such a source would generate high proportions of lithic components and these are not recorded. Changes in grain size may not be significant because they only reflect a slight increase in current speeds. However, it is worth noting that grains of quartz and chlorite should not be of the same size as Baali indicates because their disparate shapes impose a contrasting hydrodynamic behaviour. The data on Aeronian patterns of grain size variation seem to us indisputable because this is precisely the line of reasoning which we applied to identify an eastern source at lower levels. We conceded in our paper that our model may not be applicable to the Aeronian of Oslo–Asker (Braithwaite et al. 1995, p. 213) and are happy to accept a westerly derivation for this new sediment entering the basin. The new source of sediment, coupled with the complex interplay of eustacy, fault movement and (in Hadeland at least) the continued derivation of sediment from the east or north-east, may help to explain the anomalies and differences in proximality and palaeocommunity distribution noted in our paper and in Baarli's comments.

C. A palaeoslope deepening from west to east in Oslo–Asker during the Aeronian could result from increased fault movement on the easterly bounding fault or reflect the new influx of siliciclastic sediment from the west. In the light of the new petrological information, we are happy to accept the latter. The development of a *Clorinda* community in the lower part of the Leangen Member in Asker while the shallower water *Sticklandia* community continued in Oslo (albeit with marginal *Clorinda–Stricklandia* associations developed periodically) does need further study. Although the *Clorinda* faunas only occur between 195 m and 245 m in the composite Solvik Formation section at Skytterveien, this represents over a quarter of the thickness of the Leangen Member and such faunas are also present at equivalent levels at Leangbukta (Baarli 1987), 2 km to the north-east.

We concur fully with Baarli in recognizing the complexity of the Oslo Region basin within which sedimentation cannot be interpreted in terms of a simple geometry or sediment distribution. Indeed, the effects and relative contributions of the various parameters changed both in space and in time. Our intention has been to assess the applicability of ideas developed for one segment of the basin across the Ordovician–Silurian boundary, in the context of the basin as a whole. Baarli's comments have furthered and helped refine this assessment.

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