Comment

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

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In *Norsk Geologisk Tidsskrift*, 1995, Vol. 75, pp. 199–218 Braithwaite, Owen & Heath describe a model for sedimentation during latest Ordovician to early Silurian time, where an easterly source of sediments is interpreted to be a general feature of the basin. They also indicate down-warping to the west and south, generating a general east–southeast to west–southwest depth gradient across the basin. This scenario may be plausible for Ordovician and earliest Silurian (Rhuddanian) time, although there are contradictory evidences from the Rhuddanian sections. For the ensuing Aeronian Stage, petrologic and sedimentary evidence found in the central Oslo Region points to a source from the west, while benthic faunal and sedimentary data corroborate a slope from west to east.

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The article by Braithwaite, Owen & Heath which appeared in N.G.T. 1995 (no. 4) is a welcome addition to the interpretation of a basin that underwent an exceedingly complex depositional history. It is especially plaudable that they analyzed the basin across the Silurian–Ordovician boundary and thus attained a larger scope. Their work implicates an important feature: a sediment source in the east, as earlier suggested by Worsley et al. (1983) and Möller (1989).

For the Silurian of the central Oslo–Asker District, an easterly to north easterly source is feasible as far as the Rhuddanian goes. Towards the east, the Myren Member of the Solvik Formation at Malmøya in Oslo has more than 20% siltstone (Worsley et al. 1983) while further west, Spirodden in Asker has only about 10% siltstone and is more rich in carbonate (Baarli 1985). An intermittent supply of sediment, as they propose, is likely. A sudden increase in silt influx occurs in the middle of the Myren Member at Malmøya and in the Løkenes Bed of the Myren Member at Spirodden. The difference in lithology, however, between the two areas may also be explained at Spirodden in Asker as being deposited on an upthrust block, thus receiving less silt and being more favorable to carbonate deposition (Baarli 1985). The real problem for the proposed model is the Modum District directly to the west of the Oslo–Asker District. Unfortunately, Braithwaite et al. (1995) omitted Modum in their conclusion and in their Fig. 5.

Braithwaite et al. (1995, their Fig. 5) imply increasing proximity and decreasing depth to the east to northeast. Malmøya in Oslo, Spirodden and Skytterveien in Asker, and Sylling in Modum lie in an approximately straight east–west line and are thus ideal for testing this model. Although the exact spatial relationships between these areas, no doubt, were different from the present, one can assume that the east–west relationship was the same (e.g. Modum was always situated west of Asker just as Asker was west of the Oslo area). Below are listed several contradictory points for applying the model of Braithwaie et al. (1995) through the full Llandovery Series.

A. Sylling in Modum to the west was emergent during the Ordovician/Silurian transition. A small-scale karst surface at the boundary testifies to this. I do not know the duration of the emergence during the Ordovician, but Owen et al. (1990) indicated that it was similar to Ringerike to the north; e.g. probably of some duration. There is a considerable gap in deposition at the beginning of the Silurian. Sedimentation did not resume until the *cyphus* graptolite Biozone of late Rhuddanian time (Baarli 1988). Meanwhile, in the Asker area, sedimentation prevailed under relatively deep conditions from the very beginning of the Silurian. The base of the Myren Member in Asker is of latest Ordovician age (Baarli & Harper 1986, Baarli 1995) with continuous deposition across the Ordovician/Silurian boundary. The graptolite facies in the Oslo Region indicate a basal Silurian age. Thus the entire Myren Member and much of the Spirodden Member in Asker, both belonging to the Solvik Formation, were deposited under relatively deep conditions before deposition resumed at Sylling in Modum. This does not, of course, prohibit an easterly source of sediment during the Rhuddanian. It does not, however, agree with down-warping to the *west* as well as south during the latest Ordovician.

B. A single source area to the east–northeast may be adequate to account for the upper Ordovician and lowest Silurian (Rhuddanian), but this changes at the base of the Aeronian (middle Llandovery). First, thin sections have been made for the Asker area (Baarli 1981 unpublished thesis). In Asker, through the Solvik Formation, there is a clear change in the petrology between the siltstones of the Myren and Spirodden members of Rhuddanian age and the siltstones to very fine sandstones of the Aeronian Leangen Member. This indicates a change in source. The first two members show a pure mix of quartz and carbonate with very rare muscovite. At the onset of the Leangen Member, muscovite becomes more common (up to 10% but commonly around 1%) together with feldspar and chlorite (Baarli 1981 unpublished thesis). The chlorites (up to 7%) are the same grain size as the quartz, indicating they came from the same source.

Second, consider siliciclastic content and grain size. During the Aeronian, the Oslo area to the east accumulated about 10% of siltstones (Worsley et al. 1983). Skytterveien in the Asker area further west, exhibits 20 to 30% mainly siltstones with minor very fine sandstones (Baarli 1985), while the Modum District shows about 50% very fine to medium sandstones interbedded with silty mudstones to muddy siltstones (Baarli 1988). All areas show appearance of minor limestone beds towards the top of the member. An easterly source is inconceivable with such a systematic increase in both amount and coarseness of siliciclastic material towards the west. During the Aeronian, a new source area to the west played a major role. I may also add that very fine sandstones occur in the Sylling Member of late-most Rhuddanian age in the Modum District (Baarli 1988). It is difficult to envision a single easterly source distributing the coarsest sediment furthest to the west.

C. Braithwaite et al. (1995) in their Fig. 5 indicate an increasing slope from east to west. That might be reasonable for the Upper Ordovician and even to some extent for the Rhuddanian, but not for the Aeronian. Let us consider evidence from depth-related faunal associations. With the exception of one apparent anomaly, the depth relationship between the Oslo and the Asker areas is consistently deeper in Oslo than in Asker, when one looks at both communities and sedimentary structures throughout the Llandovery Series.

The anomaly occurs at Skytterveien in Asker, between 175 m and 195 m of the 245 m-thick section in Asker. There is a deepening from a *Stricklandia* community to a *Clorinda* community in Asker matched by a simultaneous deepening in the Modum District (Baarli 1988). This reversal may be absent in the Oslo area where a *Stricklandia* community is reported throughout the Padda Member (Baarli 1985). However, the Oslo District has not undergone such detailed analyses of associations as the Asker and Modum districts (Baarli 1987). What is more, the associations were only preliminarily analyzed in Baarli (1985, Fig. 12) where these data occurred. Baarli (1987) reported that the *Stricklandia* community of Malmøya of Oslo area occurred in limestone beds interbedded with an *Eoplectodonta-Isorthis* association in shale. The *Eoplectodonta-Isorthis* association was interpreted as a *Clorinda* association transitional to a *Stricklandia* association. The difference in depth is therefore not as clear, although seemingly there is a short-lasting anomaly.

During the Rhuddanian, the Modum area showed slightly deeper conditions than Asker, but shallower than the Oslo Region (Baarli 1988). I introduced the idea of a peripheral bulge to explain this among other features (Baarli 1990). However, from the Aeronian on, the Modum District is consistently shallower than the Asker area (Baarli 1987). This is despite the deepening in Modum simultaneous with gradual shallowing in Asker as quoted by Braithwaite et al. (1995). What you do find, is an initial deepening in both districts followed by a shallowing (Baarli 1988). The shallowing in the Modum District, however, is much more rapid and pronounced than in Asker. The shallowing in Modum is properly followed by a deepening, but not to the extent that deeper conditions prevail in Asker. The slope between the two is never reversed after the onset of the Aeronian. After the minor possible anomaly near the onset of the Aeronian, the Oslo Region also follows the same pattern. It was located at the deepest end of the west–east transect from the Modum through Asker to the Oslo districts.

During Aeronian time, the evidence of increasing proximity toward the west across the Oslo–Asker–Modum transect is clear from trends in sediment distribution and size. A new westerly source area became significant. Likewise, an east to west-dipping slope existed during all or at least part of Aeronian time, as interpreted from communitites and proximality analysis (Baarli 1987). The Rhuddanian situation, however, is less clear and could fit the model of Braithwaite et al. (1995).

The Oslo Region is obviously not a simple basin with a constant proximal to distal gradient. Bjørlykke (1983) pointed out several of the anomalies and used tectonics to explain them (e.g., the emergence of the Mjøsa area with subsidence further south during the Ordovician to Silurian transition and the reversal during Telychian time when the Mjøsa and Hadeland Regions seem to be the deeper regions). Möller (1989) explained the latter reversal by introducing moving shoals and Baarli (1990) explained the same by a peripheral bulge. In addition, Brenchley & Newall (1980) and Stanistreet (1983) as well as Braithwaite et al. (1995) used down-faulting of blocks to explain the anomalies and basin configuration. New interpretations are needed and welcome since there are still many pieces missing in the picture and none of the above explanations are fully satisfactory on their own.

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References

Baarli, B. G. 1981: En analyse av bentiske fossil-samfunn og faciesvariasjoner i Solvik Formasjonen (Undersilur) i Asker. Unpublished cand. scient thesis.

Baarli, B. G. 1985: The stratigraphy and sedimentology of the early Llandovery Solvik Formation, Central Oslo Region, Norway, *Norsk Geologisk Tidsskrift 65*, 255–275.

Baarli, B. G. 1987: Benthic faunal associations in the Lower Silurian Solvik Formation of the Oslo-Asker Districts, Norway. *Lethaia 20*, 75–90.

Baarli, B. G. 1988: Bathymetric co-ordination of proximality trends and level-bottom communities: a case study from the Lower Silurian of Norway. *Palaios 3*, 577–587.

Baarli, B. G. 1990: Peripheral bulge of a foreland basin in the Oslo Region during the early Silurian. *Palaeogeography, Palaeoclimatology, Palaeoecology 78*, 149–162,

Baarli, B. G. 1995: Orthacean and strophomenid brachiopods from the Lower Silurian of the central Oslo Region. *Fossils and Strata No. 39*, 1–93.

Baarli, B. G. & Harper, D. A. T. 1986: Relict Ordovician brachiopod faunas in the Lower Silurian of Asker, Oslo Region, Norway. *Norsk Geologisk Tidsskrift 66*, 87–98.

Bjørlykke, K. 1983: Subsidence and tectonics in late Precambrian and Palaeozoic sedimentary basins of southern Norway. *Norges Geologiske Undersøkelse Bulletin 380*, 59–172.

Braithwaite, C. J. R., Owen, A. O. & Heath, R. A. 1995: Sedimentological changes across the Ordovician–Silurian boundary in Hadeland and their implications for regional patterns of deposition in the Oslo Region. *Norsk Geologisk Tidsskrift 47*, 199–218.

Brenchley, P. I & Newall, G. 1980: A facies analysis of Upper Ordovician regressive sequences in the Oslo Region of Norway – a record of glacio-eustatic changes. *Palaeogeography, Palaeoclimatology, Palaeoecology 31*, 1–38.

Möller, N. K. 1989: Facies analysis and palaeogeography of the Rytteråker Formation (Lower Silurian, Oslo Region, Norway). *Palaeogeography, Palaeoclimatology, Palaeoecology 69*, 167–192.

Owen, A. W., Bruton, D. L., Bockelie, J. F. & Bockelie, T. G. 1990: The Ordovician succession of the Oslo Region, Norway. *Norges Geologiske Undersøkelse, Special Publication 4*, 1–54.

Stanistreet, I. G. 1983: Contemporaneous faulting in the Upper Ordovician of the Oslo–Asker District, Norway, and its significance for the development of the Oslo Basin. *Sedimentary Geology 37*, 133–150.

Worsley, D., Aarhus, N., Bassett, M. G., Howe, M. P. A., Mørk, A. & Olaussen, S. 1983: The Silurian succession of the Oslo Region. *Norges Geologiske Undersøkelse Bulletin 384*, 1–57.