Journal of the Geological Society

Discussion on palaeomagnetism, magnetic fabrics and the structural style of the Hornelen Old Red Sandstone, Western Norway

Journal of the Geological Society 1990; v. 147; p. 411-416
doi: 10.1144/gsjgs.147.2.0411

Journal of the Geological Society, London, Vol. **147,** 1990, pp. 411–416, 4 figs. Printed in Northern Ireland

Discussion on palaeomagnetism, magnetic fabrics and the structural style of the Hornelen Old Red Sandstone, Western Norway

Journal, Vol. 145, 1988, pp. 413–430

M. G. Norton, W. J. Wilks & S. J. Cuthbert write: In their recent paper Torsvik *et al.* (1988) presented the results of a survey of palaeomagnetic and magnetic fabric data from the Hornelen Devonian in western Norway.

We wish to comment on the following aspects:

(1) The nature of the eastern boundary of the Hornelen Devonian;

(2) The evidence presented against the accepted interpretation of near coincidence of present tectonic boundaries with boundaries tectonically active during sedimentation.

In addition there are a number of points of fact which we would like to challenge which are dealt with at the end of this discussion.

(1) Torsvik *et al.* (1988) refer to the eastern boundary of the Hornelen Devonian as an unconformity complete with 'well-preserved weathering profiles'. They give no details and refer only to a published abstract (Ramsay *et al.* 1987) which itself does not mention the unconformity, although this observation overturns previous interpretations of the contact as a fault (Bryhni 1963, 1978; Steel *et al.* 1985). We have recently examined this boundary at a number of localities (Fig. 1). The structure of the boundary was found to be very similar at all localities (Fig. 2). The basal *c.* 800 m of the section below the Devonian consists of overall gently westward-dipping mylonitic gneisses. A strong west-plunging mineral elongation lineation is developed which, together with secondary shear structures and rotated feldspar porphyroclasts, indicate an overall 'top down to the west' sense of movement. Some 150 m beneath the boundary the protolith of the mylonite changes from orthogneiss to dominantly feldspathic quartzite. In the top 50 m the mylonitization becomes noticeably more intense, locally forming an ultramylonite. Within this part of the section all kinematic indicators are consistent with those found below. From 20 m below the contact the mylonite becomes locally brecciated with a chlorite matrix and veins of quartz and pseudotachylyte. Both the degree of brecciation and the volume of rock involved increase upwards until the rock becomes a cataclasite with clasts of mylonite and ultramylonite (Fig. 3); unlike the unconformable contact with the Devonian in the west of the Hornelen outcrop (Bryhni 1978) the basement is not reddened here. This rock type forms the last 3–4 m of the section; generally it was possible to find exposure within a metre of the actual contact. The immediately overlying Devonian sediments are cut by closely spaced fractures containing quartz and epidote. The foliation in the mylonite is very closely parallel to the contact as marked by this cataclasite for at least 200 m below (Fig. 4). A similar zone of mylonite is found adjacent to the entire southern and northern margins of the basin. None of the lithologies have features that can be ascribed to weathering processes and these observations leave little doubt that the boundary is tectonic.

Additional evidence for this interpretation comes from orientation of the boundary and the bedding in the overlying Devonian. Structure contour maps on the boundary show that it has an open synclinal form plunging to the west at *c.* 20°. Bedding in the Devonian is visible at most localities. It is seen to dip to the east at *c.* 20°–30°, locally up to 80° (Fig. 4). The bedding cutoff angle of *c.* 40°–80° cannot be explained by an unconformity.

Finally the clasts found in the Devonian immediately above the contact do not reflect the underlying lithologies. No clasts of mylonite or cataclasite have been found at any locality. At most localities the dominant clast types are undeformed gabbro and diorite, non-mylonitic quartzites and granitic gneisses, lithologies which are not represented at all in the rocks immediately beneath the Devonian in the Hyenfjord area (Bryhni 1978; Cuthbert unpublished data). Only a tectonic contact with a major displacement can explain the observed boundary to the east of the Hornelen Devonian.

(2) The southern and northern boundaries of Hornelen have been recognized as a post-depositional, higher angle faults (the Haukå and Bremanger Faults) by Bryhni *et al.* (1981) and Norton (1986, 1987). These faults which downthrow towards the basin appear to represent the graben structure as proposed by Torsvik *et al.* (1988). However, they clearly follow and locally cut out the mylonite zone running beneath the basin.

In our interpretation the later fault on the northern margin for the most part reactivates the top of the mylonite zone so that here the present margin matches exactly the original margin. To the south of Hornelen, however, the later fault is clearly cross-cutting (Steel 1986) and its displacement increases to the west. In the western part of the basin near Haukå the continuous fringe of fanglomerates along the southern margin disappears, suggesting that the present margin in this area may be a few kilometres offset from the original margin.

Although these later faults do exist the sedimentological arguments for the present margins being generally near coincident with the marginal faults active during deposition appear unequivocal as repeatedly demonstrated by the extensive studies of Steel and his co-workers (see review in Steel *et al.* 1985). Torsvik *et al.* (1988), in contrast, argued that the present outcrop of the Devonian is a down-faulted relict of a much larger basin because 'a number of sandstone horizons (up to several hundred metres in outcrop width) strike into the marginal faults where they are brutally [*sic*] truncated'. However, sediment facies developed along active faults may vary with time; indeed the juxtaposition of fine- and coarse-grained facies against the fault scarp is a natural consequence of the response of depositional systems

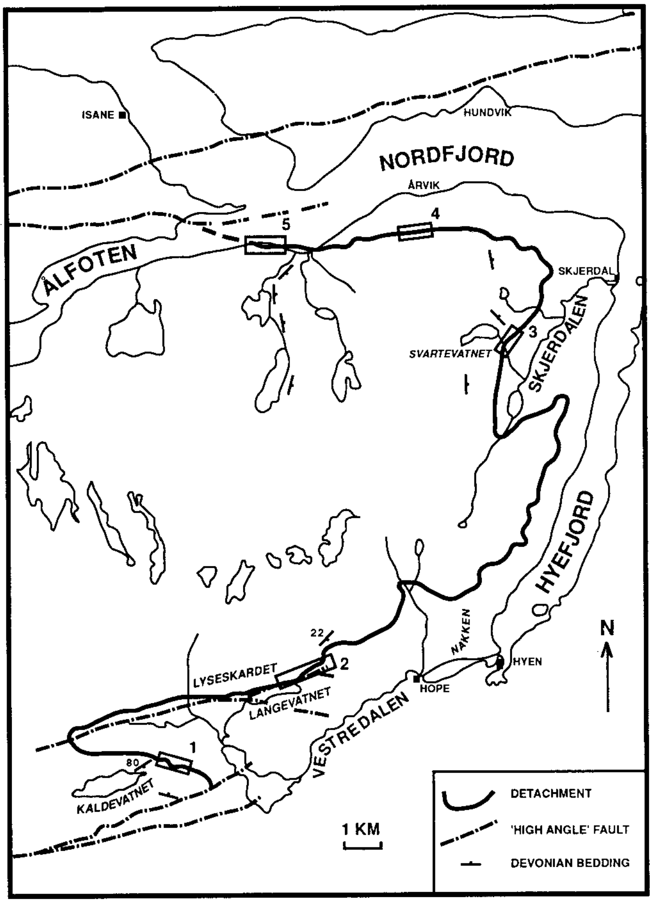

Fig. 1. Location map of the eastern margin of the Hornelen Devonian, showing localities visited in this study (1–5).

to fault activity (e.g. Leeder & Gawthorpe 1987). These observations are consistent with the previously accepted interpretation of partial, minor reactivation of the original syndepositional faults to the north and south of the basin by later (Mesozoic?) ENE–WSW faults.

We would also like to challenge a number of statements which appear in their paper.

(i) 'Plant and fish fossils found in the upper part of the succession indicate an upper Lower Devonian age' (p. 413).

Both flora and fauna indicate a Middle Devonian age (Hoeg 1936; Jarvik 1949).

(ii) 'Pebbles in conglomerates along the southern margin of the Devonian outcrop are identified as coming from the surrounding Precambrian meta-anorthosite/gneisses which belong to the Møre Window of the Western Gneiss Region' (p. 413).

Clast types in the conglomerates of the southern margin fans are dominated by quartzites (*c.* 90%) with subordinate gneisses and schists; no convincing anorthosite clasts have been found (Cuthbert unpublished data; I. Bryhni pers. comm.). Also the area of mainly mylonitic gneisses and quartzites to the south of the Hornelen Devonian are not typical of the Møre Window lacking evidence of a high-*P* metamorphism (Kildal 1971; Cuthbert unpublished data).

(iii) 'The predominant foliation in the metamorphic rocks of the basement, locally mylonitic, is essentially Scandian in age'.

Until radiometric dating has been carried out in this area, with its prolonged deformation history, we consider such an unqualified statement to be extremely unwise.

(iv) '. . . a late Devonian/early Carboniferous age. These data are thought to reflect magnetic resetting during the crustal uplift history of the Svalbardian (Solundian) Orogeny . . . and apparently conform to an $^{39}Ar/^{40}Ar$ (biotite) age of 375 Ma obtained from Statlandet (Lux 1985) . . .'.

375 Ma represents a middle Devonian or lowermost upper Devonian age on all recent suggested time scales; (e.g. Harland *et al.* 1982, upper Givetian). This date cannot be used to support their hypothesis, especially as combined with the hornblende data from the same paper it indicates continuous uplift of that part of the Western Gneiss Region from the beginning of the Devonian, rather than a discrete 'Solundian' event.

In summary, while we applaud the new palaeomagnetic data of Torsvik *et al.* (1988) and concur that Mesozoic faulting was a significant episode in western Norway we wish to reaffirm previous interpretations of the area. The Hornelen Basin is in clear tectonic contact with its basement to the east and the present basin margins are substantially similar to those at the time of deposition, despite later reactivation. The suggestion that the eastern contact is unconformable is not supported by our widespread observations. The nature of the tectonism responsible for the observed mylonitization and cataclasis is presently under study, but all our observations to date are consistent with an extensional detachment (Norton 1986).

We wish particularly to thank I. Bryhni for useful discussions on the nature of the eastern boundary. MGN thanks Fina (UK) and Fina Exploration Norway for support under the COCO project. WW and SJC gratefully acknowledge fieldwork support by NERC.

Michel Séranne writes: In a recent paper, Torsvik *et al.* (1988) presented a comprehensive magnetic fabric analysis of the Hornelen ORS sediments in Norway. On the basis of their results they claim that the synclinal geometry of the strata, together with the faults bounding the basin are post-Devonian in age and they conclude that 'the graben-like form of the Hornelen massif is essentially one of Mesozoic construction'. Although I acknowledge a survey that provides us with important new data, I question conclusions that do not take into account many previously published geological observations such as: the nature of the basin boundaries, the geometry of the basin-fill and the nature of the deformation affecting the sediments. I believe that the authors have disregarded the problem of the formation of the Hornelen basin and of the other similar ORS basins of the area: Kvamshesten, Håsteinen (Torsvik *et al.* 1986, 1987) and Solund.

Nature of the basin boundaries. The authors state that the eastern margin of Hornelen is an unconformity, but surprisingly do not give evidence or a reliable reference even though it contradicts all published papers on the subject (see the review in Séranne & Séguret 1987). This low-angle contact presents fault-rock associations and kinematic indicators consistent with a westward dipping low-angle normal fault (Séranne & Séguret 1987). As for the

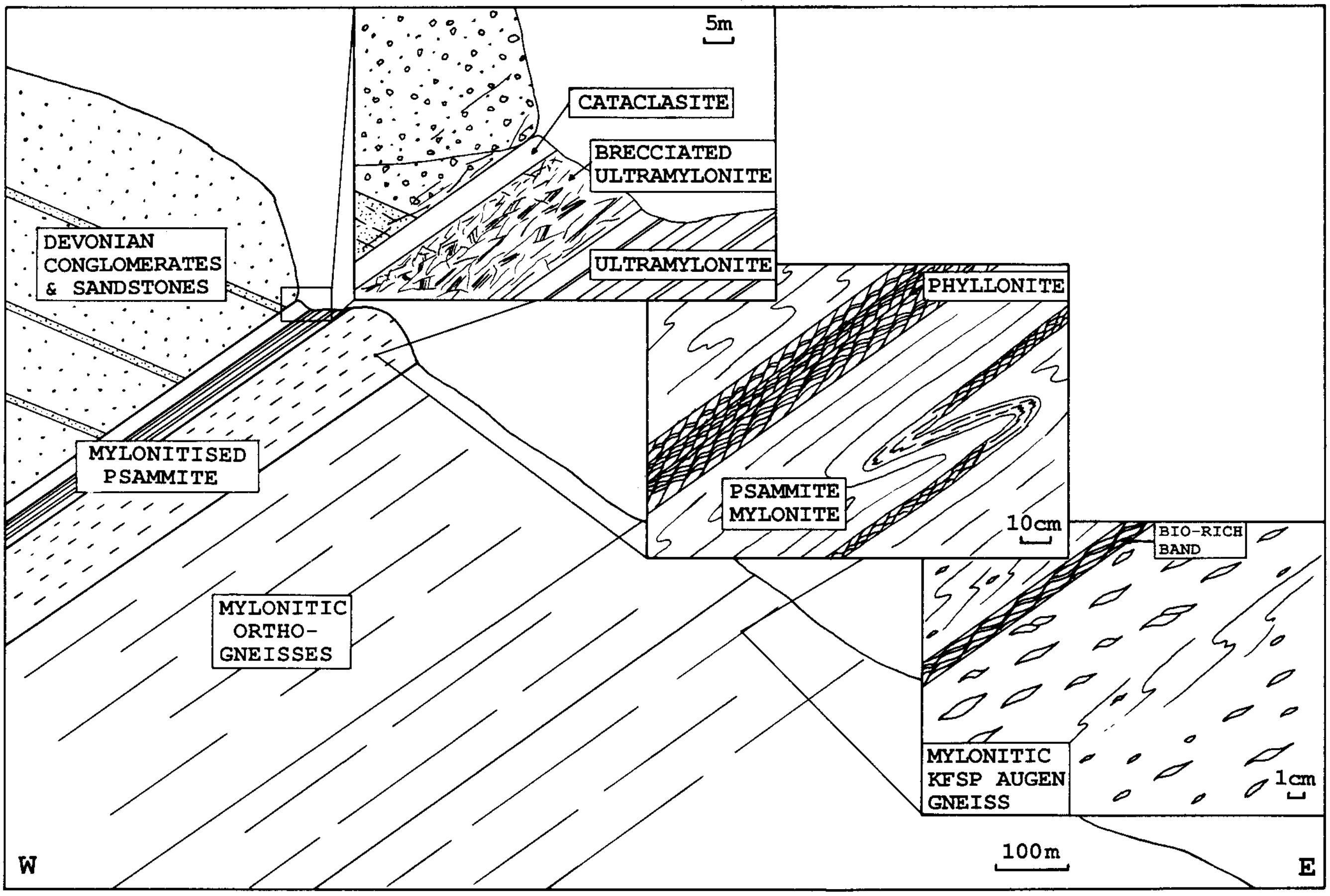

Fig. 2. Schematic composite section through the eastern margin of the Hornelen Devonian. N.B. locally the ultramylonites are cut out by the cataclasite.

north and south faulted margins, they display sub-horizontal lineations and slickensides and the associated shear criteria argue for a dextral and sinistral displacement for the northern and southern marginal faults, respectively (Chauvet & Séranne 1988; Séranne 1988). I therefore argue (following Hossack 1984) that these faults are transfer faults of the eastern low-angle detachment.

Internal organization of basin-fill. The Devonian strata are organized in *c.* 200 coarsening upward cycles (Steel 1976) that regularly dip 25°E along an axial section, thus giving a total calculated stratigraphic thickness of *c.* 25 km (Bryhni 1964). This feature constitutes the essential point in the discussion about Hornelen basin formation (e.g. Steel *et al.* 1985) but has been ignored by the authors. The bedding

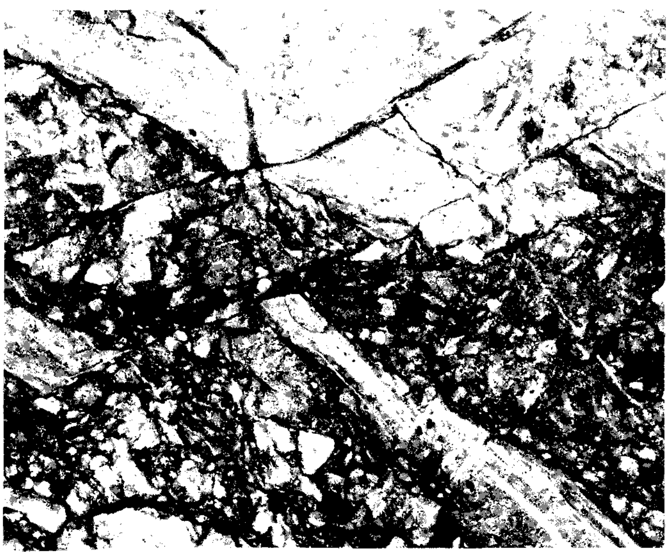

Fig. 3. Thin section micrograph of cataclasite from *c.* 2 m beneath the Devonian contact, 900 m ENE of Kaldevatnet (GR 32VLP278466, Locality 1) (field of view is 3 mm across plane light). A long history of brecciation is observed with early cataclasite being cut by several generations of later veins and microfaults.

Fig. 4. View from the contact at the foot of Lyseskardet looking ENE towards Nakken (Fig. 1) showing the orientation of the bedding in the Devonian, the contact and the foliation in the underlying mylonites.

steepens and is bowed against the transfer faults. Accurate mapping in the northern area of Hornelen revealed progressive syntectonic unconformities within the steeply dipping strata (Chauvet & Séranne 1988). Sequential restoration of the superposed internal unconformities to horizontal position demonstrates basement uplift and dextral translation along the northern lateral ramp during deposition of Devonian sediments (Séranne 1988). The synclinal geometry of the basin is therefore a result of basin formation rather than of late compression. Furthermore, this view supports the interpretation that the present north and south margins are the original lateral ramps (with minor later reactivation) as also convincingly demonstrated by R. Steel and co-workers (Steel *et al.* 1985).

Magnetic/tectonic fabrics. The magnetic foliation is significantly parallel to bedding and magnetic lineation is parallel to the easterly plunging syncline axis. Torsvik *et al.* (1988) indicate that most of the magnetization (the 'A component') was acquired during folding. The presence of progressive syntectonic unconformities on the margins of the basin implies that most of the folding occurred during basin development. Consequently, unlike the authors, we must consider the magnetization of the sediment as an early event in the basin history. However, the authors point out that the magnetic lineation is unlikely to be of primary origin. An alternative would be to consider the magnetization as a result of an early synsedimentary deformation related to basin formation. Synsedimentary deformation was pointed out in the neighbouring basin of Kvamshesten (Skjerlie 1971; Bryhni & Skjerlie 1975) and deformation of unconsolidated sediment (therefore very early in basin development) was described in every Devonian basin of the area (Séranne 1988). Strain and stress analysis in the sedimentary-fill revealed that deformation (including the development of cleavage) was produced by basin formation in response to E–W extension (Séranne & Séguret 1987). The 'B component', mostly represented along the north and south margins, may be the result of a reactivation of the lateral ramps. However, the dating of the tectonic events with the apparent pole wander may be discussed and the authors 'employed it as a working model'. The pole position confidence ellipses provided by the Devonian basins (fig. 18a) are well gathered around the Devonian mean pole position thus suggesting a Devonian magnetization (A component) rather than a Lower Carboniferous one. Furthermore, the pole positions corresponding to the B component (assumed to be post-Devonian) seem too scattered to support a relevant interpretation.

In conclusion, although I congratulate Torsvik and co-authors for their contribution to our knowledge of the palaeomagnetism of the area, I maintain that the syn-folding magnetic fabric detected in the sedimentary-fill of Hornelen basin cannot be the result of a late event. Most of the magnetic data fit with extensional tectonics responsible for the basin formation, according to the model presented in Séranne & Séguret (1987). Up until now, the authors have failed to explain the evidence in favour of an extensional model for the basin formation.

T. H. Torsvik, B. A. Sturt, D. M. Ramsay, D. Bering & P. R. Fluge reply: We note with interest the claim of Séranne that we have disregarded the problems of Devonian basin generation in Western Norway. These problems were not overlooked, but as our studies shed no new light on this issue we did not address it. Rather, we confined ourselves primarily to the deformation of the basins and presented alternatives to the present fashion of attributing all observed deformation and faulting in the Western Norwegian Devonian to syn-depositional deformation. Most notably, we assert that the value of structural markers such as shear-criteria is circumstantial unless the temporal relationship is known. Conversely we argue that Scandian and late to post-Devonian structures have been blended with structures with relevance to basin formation.

In the introduction of our paper we aver that no evidence has been presented for a 'syn-depositional Devonian low-angle fault' along the Eastern margin of Hornelen. We are not totally rejecting a possible detachment, but the papers by Bryhni (1964) and Séranne & Séguret (1987) provide no details on these matters. In retrospect, contact-relationship details given by Norton *et al.* probably provide a better frame for a possible Devonian detachment. (A reply is in preparation.)

Concerning the magnetic fabric and palaeomagnetic data, Séranne appears to be somewhat confused in his compounding of these two recurrently unrelated data-types. With regard to the origin of remanence component A, a late-syn or post-fold origin was indicated, but this is statistically arguable. It is correct as Séranne points out that remanence acquisition may relate to syn-depositional folding. In this case the remanence must be 'near primary' and final sediment consolidation, dewatering and possible hematite pigmentation occurred at a late syn-fold or post-fold state. In the paper and elsewhere (Torsvik *et al.* 1987) we argue that the overall folding and cleavage development are the product of post-depositional deformation, although we acknowledge local evidence for syn-depositional deformation. From Håsteinen (Torsvik *et al.* 1987) and Solund (Torsvik *et al.* in prep.) penetrative regional fabrics are developed internally in conglomerate boulders. This could not have been achieved by soft-sediment deformation. In addition, the indications of a 'primary' pre-fold magnetization in the central-western part of the Kvamshesten Basin (Smethurst pers. comm.) suggest that the sediments were consolidated before folding.

With regard to the magnetic lineations these are clearly more consistent than palaeo-current indicators, as is the case for the Solund massif where they are clearly of tectonic origin (Torsvik *et al.* in prep.).

Precise age-dating by means of palaeomagnetic data requires a good knowledge of the apparent polar wander path (APWP). Due to the lack of good reference data from Norway there are problems in assigning a precise remanence acquisition age. Seen in relation to new palaeomagnetic data from well-dated Lower Carboniferous rocks from the British Isles, however, the age of the A components in Western Norway appears to be Upper Devonian to Lower Carboniferous (Torsvik *et al.* 1989; 1990).

The European Permian pole-position is much more precisely determined, and its position on the map has essentially remained unchanged for several decades. The B component derived from Hornelen is not precisely known, but is clearly of post-Permian origin. If we consider all the magnetic overprints from Western and Central Norway, however, it is evident that there is a certain spread in the palaeomagnetic 'ages', and they define a spread from Permian to Upper Jurassic times. This, however, can be related to a protracted fault-activity reactivating older structures. This is well demonstrated on Atløy, where the palaeomagnetic 'ages' show a clear correlation with different generation of fault-breccias (Sturt & Torsvik in prep.).

In conclusion we did not ignore ideas of an extensional collapse to generate the Devonian Basins. On the contrary this was indicated as phase 2 in our fig. 18. We prefer, however, a phase of balanced compression to explain the complex fold geometry, cleavage development and shearing in the Devonian rocks. Finally, we would point out that a number of the extensional criteria presented as evidence for Devonian extension could relate to Permian and younger extensional deformation. In addition, the prominent E–W high-angle faults like the southern margins of Hornelen and Håsteinen are unlikely to represent lateral-ramps in the detachment models. This was also stressed by Norton (1987) whose extensional model is not consistent with the model presented by Séranne & Séguret (1985, 1987). The inverted bedding close to the Northern Marginal fault of Hornelen is also a puzzling feature, if it does not result from post-depositional folding or tightening of already syn-depositional folds. We submit that the geometry of the basins requires the original boundary faults to have been situated close to the present exposed faults, and that the observed deformation features and fault-geometries may have resulted as a combination of Devonian extension and subsequent deformation phases. In essence we argue for several phases of post-depositional deformation, some only local in importance, probably initiated in Permian–Early Mesozoic times, whereas Séranne argues that tectonism in Western Norway had finally ceased by Middle–Devonian times. Considerable thicknesses of extensional mylonites are preserved in other Caledonian sedimentary basins that have subsequently suffered thrusting, folding and crustal shortening, e.g. the Silurian basin of North Connemara, W. Ireland (Williams & Rice, 1989; P. Ryan, pers. comm.).

References

BRYHNI, I. 1963. Relasjonen mellom sencaledonisk tektonikk og sedimentasjon ved Hornelens og Håsteinens devon. *Norges geologiske undersøkelse*, **223**, 10–25.

—— 1964. Migrating basins on the Old Red Continent, *Nature*, **202**, 384–385.

—— 1978. Flood deposits in the Hornelen basin, west Norway. *Norsk geologisk Tidsskrift*, **58**, 273–300.

—— & SKJERLIE, F. J. 1975. Syn-depositional tectonism in the Kvamshesten district (Old Red Sandstone) western Norway. *Geological Magazine*, **112**, 593–600.

——, BOCKELIE, J. F. & NYSTUEN, J. P. 1981. *Excursions in the Scandinavian Caledonides: The Southern Norwegian Caledonides Oslo–Sognefjord–Ålesund.* Oslo.

CHAUVET, A. & SÉRANNE, M. 1988. Microtectonic evidence of Devonian extensional westward shearing in southwestern Norway, *In*: GAYER, R. (ed.) *The Caledonide Geology of Scandinavia.* Graham & Trotman, 245–254.

HARLAND, W. B., COX, A. V., LLEWELLYN, P. G., PICKTON, C. A. G., SMITH, A. G. & WALTERS, R. 1982. *A geologic time scale.* Cambridge University Press, Cambridge.

HOEG, O. A. 1936. Norges fossile flora. *Naturen*, **7–21**, 47–64.

HOSSACK, J. R. 1984. The geometry of listric growth fault in the Devonian basins of Sunnfjord, W. Norway. *Journal of the Geological Society, London*, **141**, 629–637.

JARVIK, E. 1949. On the Middle Devonian crossopterygians from the Hornelen field in western Norway. *Universitet i Bergen Årbok 1948, Naturvidenskapelig Raekke No. 8*, 1–48.

KILDAL, E. S. 1970. *Geologisk kart over Norge, berggrunnskart Måløy. 1:250 000*, Norges geologiske Undersøkelse.

LEEDER, M. R. & GAWTHORPE, R. L. 1987. Sedimentary models for extensional tilt-block/half-graben basins. *In*: (eds.) COWARD, M. P., DEWEY, J. F. & HANCOCK, P. L., *Continental Extensional Tectonics*, Geological Society London Special Publication, **28**, 139–152.

LUX, D. R. 1985. K/Ar ages from the Basal gneiss region, Statlandet area, western Norway. *Norsk geologisk Tidsskrift*, **65**, 277.

NORTON, M. G. 1986. Late Caledonide extension in western Norway : a response to extreme crustal thickening. *Tectonics*, **5**, 195–204.

—— 1987. Nordfjord–Sogn Detachment, W. Norway. *Norsk geologisk Tidsskrift*, **67**, 93–106.

RAMSAY, D. M., STURT, B. A., TORSVIK, T., KISCH, H. J. & BERING, D. 1987. The structural evolution of the Devonian sequence of Kvamshesten, Western Norway. (Abstract). *Terra Cognita*, **7**.

SÉRANNE, M. 1988. *Tectonique des bassins dévoniens de Norvège: Mise en évidence de bassins sédimentaires en extension formés par amincissement d'une croute orogénique épaissie.* Thèse de Doctorat, Université de Montpellier.

SÉRANNE, M. & SÉGURET, M. 1987: The Devonian Basins of western Norway: Tectonics and kinematics of an extended crust, *In*: COWARD, M. P., DEWEY, J. F. & HANCOCK, P. L. (eds) *Continental Extensional Tectonics*, Geological Society, London, Special Publication, **28**, 537–548.

SKJERLIE, F. J. 1971. Sedimentasjon og tektonisk utvikling i Kvamshesten devonfelt, Vestlandet, *Norge Geoliske Undersøkelse*, **270**, 77–108.

STEEL, R. J. 1976. Devonian basins of Western Norway: sedimentary response to tectonism and varying tectonic context, *Tectonophysics*, **36**, 207–224.

—— 1986. *A field guide to Hornelen Basin (Devonian)—a deep, fault-controlled, late-orogenic basin in western Norway.* Geological Institute, University of Bergen.

——, SIEDLECKA, A. & ROBERTS, D. 1985. The Old Red Sandstone basins of Norway and their deformation: a review, *In*: STURT, B. A. & GEE, D. G., (eds). *The Caledonide orogen—Scandinavia and related areas.* J. Wiley & Sons, New York, 293–316.

TORSVIK, T. H., STURT, B. A., RAMSAY, D. M. & KISCH, H. J. & BERING, D. 1986. The tectonic implications of Solundian (Upper Devonian) magnetization of the Devonian rocks of Kvamshesten, W. Norway, *Earth and Planetary Science, Letters*, **80**, 337–347.

——, ——, —— & VETTI, V. 1987. The tectono-magnetic signature of the Old Red Sandstone and pre-Devonian strata in the Hasteinen area, W. Norway, and implciations for the later stages of the Caledonian orogeny, *Tectonics*, **6/3**, 305–322.

——, ——, ——, BERING, D. & FLUGE, P. R. 1988. Palaeomagnetism, magnetic fabrics and the structural style of the Hornelen Old Red Sandstone, western Norway, *Journal of the Geological Society, London*, **145**, 413–430.

——, LYSE, O., ATTERÅS, G. & BLUCK, B. J. 1989. Palaeozoic palaeomagnetic data from Scotland and their bearing on the British

Apparent Polar Wander Path. *Physics of the Earth and Planetary Interiors,* **55,** 93–105.
——, SMETHURST, M. A., BRIDEN, J. C. & STURT, B. A. 1990. A review of Palaeozoic palaeomagnetic data from Europe and their palaeogeographical implications. *In*: MCKERROW, W. S. & SCOTESE, C. R. (eds) *Palaeozoic and Palaeogeography Biogeography.* Journal Geological Society London Memoir (in press).
WILLIAMS, D. M. & RICE, A. H. N. 1989. Low-angle extensional faulting and the emplacement of the Connemara Dalradian, Ireland. *Tectonics,* **8,** 417–428.

M. G. NORTON & W. J. WILKS, Department of Geology, Royal Holloway & Bedford New College, Egham Hill, Egham, Surrey TW20 0EX, UK.

S. J. CUTHBERT, Department of Geology, The University, Glasgow G12 8QQ, UK.

M. SERANNE, Department of Geology, Imperial College of Sciences, Technology and Medicine, Prince Consort Road, London SW7 2BP, UK.

T. H. TORSVIK, Department of Earth Sciences, University of Oxford, Oxford OX1 3PR, UK.

B. A. STURT, Geological Survey of Norway, PO Box 3006, N-7001 Trondheim, Norway.

D. M. RAMSAY, Department of Geology, University of Dundee, Dundee DD1 4HN, UK.

D. BERING, Institute of Geology, University of Bergen, N-5000 Bergen, Norway.

P. R. FLUGE, Institute of Geophysics, University of Bergen, N-5000 Bergen, Norway.