THE ORDOVICIAN OF NORWAY

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Ordovician deposits in Norway outside the main Caledonian belt are restricted to the Oslo Region and Digermulen. Sedimentation extended from a stable platform in the east (Balto-Scandian area) passing into a lime mud deposition of the foreland (Oslo-Scania) and westwards for an unknown distance. Parautochthonous sediments along the edge of the fold

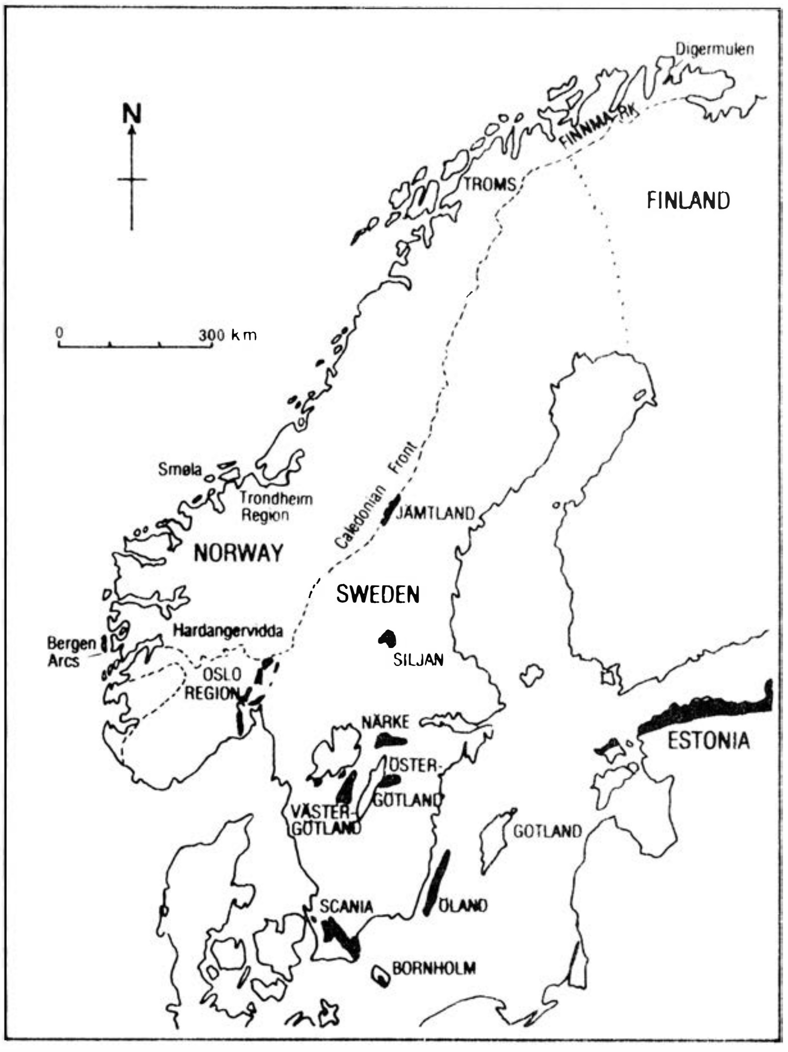

Figure 1. Map of Scandinavia showing location of Ordovician outcrops. From Bruton, Lindström & Owen, in prep.

belt show this distance to have been at least 150 km. Recent data (Nystuen 1981; Ramberg & Bockelie 1981) indicated that parts of the succession in the Oslo Region itself lie above planes of décollement and may have originated some distance to the north.

West of the present Norwegian coast lay the Iapetus Ocean of unknown width. Transport of ocean floor volcanic assemblages (Furnes et al. 1980) and related fossiliferous early Ordovician sediments (Bruton & Harper 1981) from west to east indicates far distant sources. The main sources of terrigenous sediments were to the north-west within the Iapetus Ocean and its Scandinavian borderland. Hypothetical sources are island chains and emergent sialic masses that either were completely detached from the main cratons or remained continuous with them at a deeper lithospheric level.

The Ordovician succession over the platform to the east is thin (commonly less than 200 m), but in the Oslo Region mean sedimentation rates were much higher (Bjørlykke 1974) and local successions approaching 1 000 m thick are known. Lateral and vertical facies changes are more marked in this region, but broadly speaking there is a series of belts which indicate a westward shallowing (Størmer 1967; Bockelie 1978). Parts of local allochthonous Ordovician successions show some similarity to the autochthonous and parautochthonous Scandinavian deposits but the overall distribution of facies and faunas is otherwise more complex.

SEDIMENTOLOGICAL AND TECTONIC HISTORY

There is a conspicuous break at the base of the system except near Oslo where the succession is complete at the Cambro-Ordovician boundary (Henningsmoen 1973; Bruton et al. 1982). Nevertheless, it is debatable whether there was an extensive regression in the early Tremadoc. The Tremadoc begins with Dictyonema Shale and ends with Ceratopyge Limestone containing a typical Ordovician shelly fauna. It is somewhat difficult to fit this succession into the pattern of gradual transgresssion, since the Dictyonema Shale can be regarded as a continuation of an Upper Cambrian black shale facies that is not likely to have been a shallow water deposit. However, the process of transgression may have been complex and iterative rather than gradual. The Dictyonema beds also occur in the parautochthonous successions along the Caledonian front as far north as Digermulen (Størmer 1940; Gee 1981).

The early Arenig marks a further transgression with the establishment of graptolite shales extending from Scania into the Oslo region and north into Jämtland (Erdtmann 1965). Like in Sweden, the development of limestones is seen locally along the western edge of the Oslo Region (Erdtmann 1965, text-fig. 7) while further west (palinspastically; north in present geography), in the parautochthonous successions, an arenaceous facies is developed (Skjeseth 1952, 1962; Størmer 1967, Fig. 9). As with the Whiterock regression in North America (Jaanusson 1979), there is evidence that the Oslo Region, including the Scanian confacies belt, underwent shallowing during the late Arenig—early Llanvirn (Jaanusson 1973). This may also be the explanation for the change from the graptolite shale environment of the Lower Arenig of the Oslo Region (Erdtmann 1965) to the 'Orthoceras Limestone'.

Superimposed on the Whiterock regressive event (which was possibly eustatic) there is a pattern of hiatuses and recommencement of sedimentation on the Baltic Shield which Jaanusson (1973, pp. 29-30) speculated to have been coupled to tectonic events within the Caledonian orogen. These phenomena are now thought to be related to early nappe movement in the west associated with the closing of Iapetus. Throughout the south-western and central Norwegian Caledonides, a number of ophiolite sequences occur along a belt some 1 000 km long (Furnes et al. 1980). Only in the Trondheim area is one such ophiolite associated with sediments containing late Arenig or younger fossils of North American aspect (Bruton & Bockelie 1980). The ophiolite sequences include the shelly faunas of the Hølonda Limestone (Neuman & Bruton 1974; S. Bergström 1979) and the graptolite faunas of the Bogo Shale (Skevington 1963; Ryan et al. 1980). Structural and geochemical analyses (Furnes 1980; Roberts 1980) suggest that obduction was complete by mid-Arenig times and this hypothesis has been extended to the dating of the time of obduction of other ophiolites (Sturt et al. 1980). Bruton & Bockelie (1980), however, have pointed out that this conflicts with current views on faunal provincialism, and suggest that obduction might have occurred later in the Ordovician. Irrespective of when obduction occurred, the sequences show that volcanic island environments existed either on or at some distance from the margin of the Baltic Shield during the early Ordovician (Bruton & Bockelie 1979, 1980; Roberts 1980). Sediments associated with these include serpentine conglomerates (Stigh 1980) some of which are fossiliferous (Bruton & Harper 1981; Holmquist 1980).

Following the Whiterock regression, renewed transgression set in during the Llanvirn. Evidence is that the phosphate content of the sediments high at the Volkhov—Kunda transition, is much reduced (Bjørlykke 1974, Table 3), sessile benthos disappears, the proportion of trilobite/echinoderm skeletal material rises, and particle size decreases. The succeeding history of the Middle and late Ordovician bears witness to the increasing influence of events in the fold belt. Thus Bjørlykke (1974, 1974a) has documented a progressive increase in geochemical similarity of the sediments in the Oslo region and those in the Trondheim area. Elements such as Mg, Fe, Ni and Cr, detrital minerals, notable chromite, and increasing chlorite/illite ratios, suggest derivation from volcanic island sources (or from old submarine volcanic rocks that emerged as a result of tectonic processes). If volcanic islands were involved, these may have been remnants of islands formed during the Arenig and later eroded during an early advance of the nappes, or active systems which also were responsible for the Middle Ordovician bentonites. These bentonites extend from the Glyptograptus teretiusculus to Diplograptus multidens zones and occur at various localities between Oslo and Bornholm and as far east as Estonia (Bergström & Nilsson 1974; Männil 1966). Some bentonite beds can be traced over long distances and represent explosive intermediate volcanism of apparently enormous proportions. Approximately at the same time as this volcanic activity, basement faulting occurred which influenced deposition of parts of the Ordovician succession in the Oslo Region (Bockelie 1978).

From the Middle Ordovician onwards, the distinction between the North American and Baltic faunas becomes less pronounced as a result of narrowing of the Iapetus Ocean (Shaw & Fortey 1977; Jaanusson 1979; Bruton & Owen 1979). Important regressive events are recorded in the Middle and Upper Ordovician successions of Norway, the first of these being a Caradoc event. Thus in the northern (Mjøsa, Opalinski & Harland 1981) and southern (Skien—Langesund, Harland 1980) parts of the Oslo Region, limestones, locally biohermal, are developed. Jaanusson (1973, pp. 12-13, 1979, A 148-149) noted that the Norwegian formations contain carbonate sediments of 'Bahaman type' and faunas indicating warm water conditions. At the Caradoc-Ashgill boundary, black shale deposits, the result of a very widespread transgression, covered much of Sweden and all but the Mjøsa district of the Oslo Region (Jaanusson 1963; Bruton & Owen 1979). This shale is regarded as a tongue of the Dicellograptus Shale of the Scanian confacies belt. Vogt (1928; 1945) argued that a supposed hiatus aroung the Caradoc-Ashgill boundary in the Oslo Region corresponds to the so-called Ekne disturbance in the Trondheim Region. Owen (1979) and Bruton & Owen (1979), however, have demonstrated that no break exists.

The most spectacular and widespread regression took place in the latest Ordovician with the development of coarse clastic sediments. Brenchley & Newall (1980) have argued that these deposits record glacio-eustatic changes. The late Ordovician regressive events were separated by phases of sedimentation in relatively deep water, culminating in the early Silurian with widely distributed graptolite shales on the Scandinavian part of the Baltic Shield. One can speculate that this was due to increased nappe loading on the western margin of the Shield. The regressive events, if correctly interpreted as eustatic, were in this case superimposed on a tectonically induced trend towards transgression.

In the fold belt, Middle and Upper Ordovician successions are known but not well correlated. New faunas of both Caradoc and Ashgill age are known from the Meldal and Hølonda areas of the Trondheim Region (R.B. Neuman pers. comm. 1981). These included the oldest known brachiopods and corals to occur in both autochthonous and allochthonous sequences from west to east. Characteristic Ashgill faunas are recorded from the Bergen, Trondheim and possibly Troms areas in Norway (Breivik 1975; Færseth & Ryen 1976; Ryen & Skevington 1976; Kollung 1979; Binns & Gayer 1980).