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THE LATE PRECAMBRIAN "SPARAGMITES" OF SOUTHERN NORWAY: A MAJOR CALEDONIAN ALLOCHTHON — THE OSEN-ROA NAPPE COMPLEX*

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ABSTRACT. The Late Precambrian sedimentary Hedmark Group ("sparagmites") of southern Norway has traditionally been considered to be parautochthonous, deposited in grabens or rift-basins within the present sparagmite region.

An allochthonous position is proposed here, from a correlation between the basal thrust planes of the Osen nappe in the southern part of the region and the Røa nappe in the northern part. This gives a minimum nappe displacement of 150 km, though the total thrust distance may be of the order of 200 to 400 km. Thus, the Late Precambrian "sparagmite basins" must have been located within the present Møre-Trøndelag region or farther west. Lateral facies variations and clast lithologies in the Hedmark Group are explained in accordance with an allochthonous origin for the Osen-Røa nappe complex. Cambro-Silurian strata of eastern foreland facies and miogeosynclinal facies occur within the Osen-Røa nappe complex, and the paleoposition of the border zone between these facies was therefore located farther west on the Baltoscandian craton than previously considered. Allochthonous and autochthonous post-Varangian sediments are arranged palinspastically to form a sequence onlapping the Precambrian basement toward the southeast. The approximately kilometer-thick epicontinental Cambro-Silurian sequence in the Oslo region was deposited partly above the Hedmark Group and partly above the basement in a depression (syneclise) elongated toward the south or southeast as a structural continuation of the Precambrian basins farther northwest on the craton. The emplacement of the Osen-Røa nappe complex and the contemporaneous decollement folding of the Cambro-Silurian sequence in the Oslo region were completed during the late Silurian or early Devonian. Higher Caledonian nappe units were emplaced above the Osen-Røa nappe complex during this main phase of deformation. Tectonic structures within the Osen-Røa nappe complex and their geometrical and genetic relations to structures of overlying nappes vary regionally and indicate a complex deformation history of the tectonic units present within the sparagmite region.

INTRODUCTION

Plate-tectonic models of the Scandinavian Caledonides include a Late Precambrian (700-630 Ma) rift phase, forming the Iapetus Ocean ("proto-Atlantic") and rift-basins along the western side of the Baltoscandian craton (Gale and Roberts, 1974; Gee, 1975; Bjørlykke, Elvsborg, and Høy, 1976).

The 3 to 4 km thick Late Precambrian Hedmark Group (Bjørlykke, Englund, and Kirkhusmo, 1967) (so-called "sparagmites") (table 1) in the sparagmite region of southern Norway (figs. 1 and 2) is considered to have been deposited in intracratonic *rift valleys* (Bjørlykke, Elvsborg, and Høy, 1976; Bjørlykke, 1978) or an *aulacogen* (Roberts and Gale, 1978) during this stage.

The Hedmark Group of basinal facies and the succeeding Cambro-Silurian strata were folded and thrust during the Caledonian orogeny. However, the degree of horizontal displacement of this sequence and hence the paleoposition of the basin have been a matter of controversy.

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TABLE 1

Stratigraphy of the Late Precambrian Hedmark Group

Mjøsa type area (Bjørlykke, 1978)		Eastern and northern part of the sparagmite region (Nystuen, this paper)	
Fossiliferous Lower Cambrian sandstone and shale			
VANGSÅS FORMATION		VANGSÅS FORMATION	
Ringsaker Quartzite Member	40 m	Ringsaker Quartzite Member	100-200 m
Vardal Sandstone Member	200 m	Vardal Sandstone Member	200-800 m
EKRE SHALE	20- 50 m	EKRE SHALE	5-250 m
MOELV TILLITE	1- 20 m	MOELV TILLITE	1-160 m
RING FORMATION			
Conglomerate, sandstone	0-200 m		
BIRI FORMATION			
Shale, limestone	100 m		
		BASALT	0- 15 m
BISKOPÅS CONGLOMERATE	0-200 m	OSDAL CONGLOMERATE	0-200 m
BIRI FORMATION		ELTA FORMATION	
Carbonate, phosphates	0- 10 m	Calcareous, sandstone, shale, carbonate	0-150 m
BRØTTUM FORMATION		RENDAL FORMATION	
Conglomerate, sandstone, shale	2000 m	Conglomerate, sandstone	2000 m
Basement not known		Crystalline basement (allochthonous)	

Since Schiøtz (1902) introduced the hypothesis of local, fault-bounded "sparagmite basins" within the outcropping area of the thick Hedmark Group sequence, this *parautochthonous basin model* (figs. 3 and 4) has been the dominating and traditional view of the tectonic position of the Late Precambrian basin facies strata in southern Norway. The tectonic and sedimentological aspects of the model have been modified and further evolved by Holtedahl (1920, 1921, 1930), Skjeseth (1954, 1963), Ramberg and Englund (1969), Englund (1972, 1973), Bjørlykke (1974a, 1978), Bjørlykke, Elvsborg, and Høy (1976), and Nystuen (1975a, 1976a).

In the parautochthonous model the basin margins were believed to be approximately coincident with the post-Caledonian Rendal, Osen, and Engerdal faults in the east and with hypothetical faults in the south and west (figs. 1-3). A basement ridge or horst between the Rendal

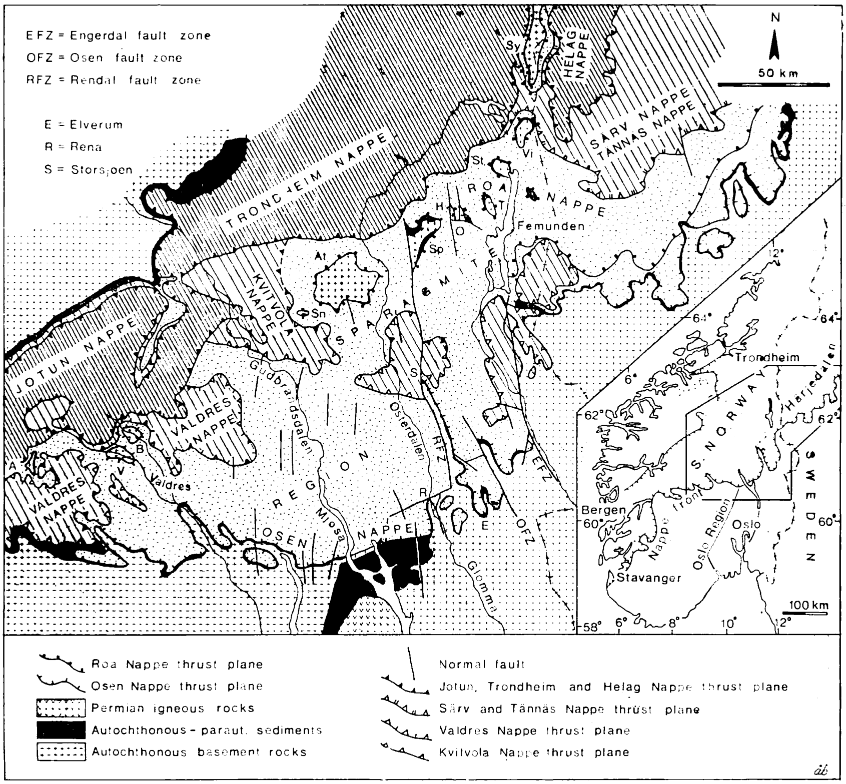

Fig. 1. Simplified tectonostratigraphic map of the sparagmite region in Southern Norway and Härjedalen (Sweden). The Hede and Veman nappes in Härjedalen (Röshoff, 1978) are included in the Røa nappe. Compiled mainly from Holtedahl and Dons (1960), Magnusson (1960), and Hossack (1978). Windows with exposed crystalline basement and autochthonous-parautochthonous sediments, from the southwest to the northeast: A = Aurland, V = Vang, B = Beito, Sn = Snødøla, At = Atnasjøen, Sp = Spekedalen (also named Finstad and Brydalen), H = Holøydalen, Ø = Øversjødalen, T = Tufsingdalen, St = Steinfjellet, Vi = Vigelen, Sy = Sylene.

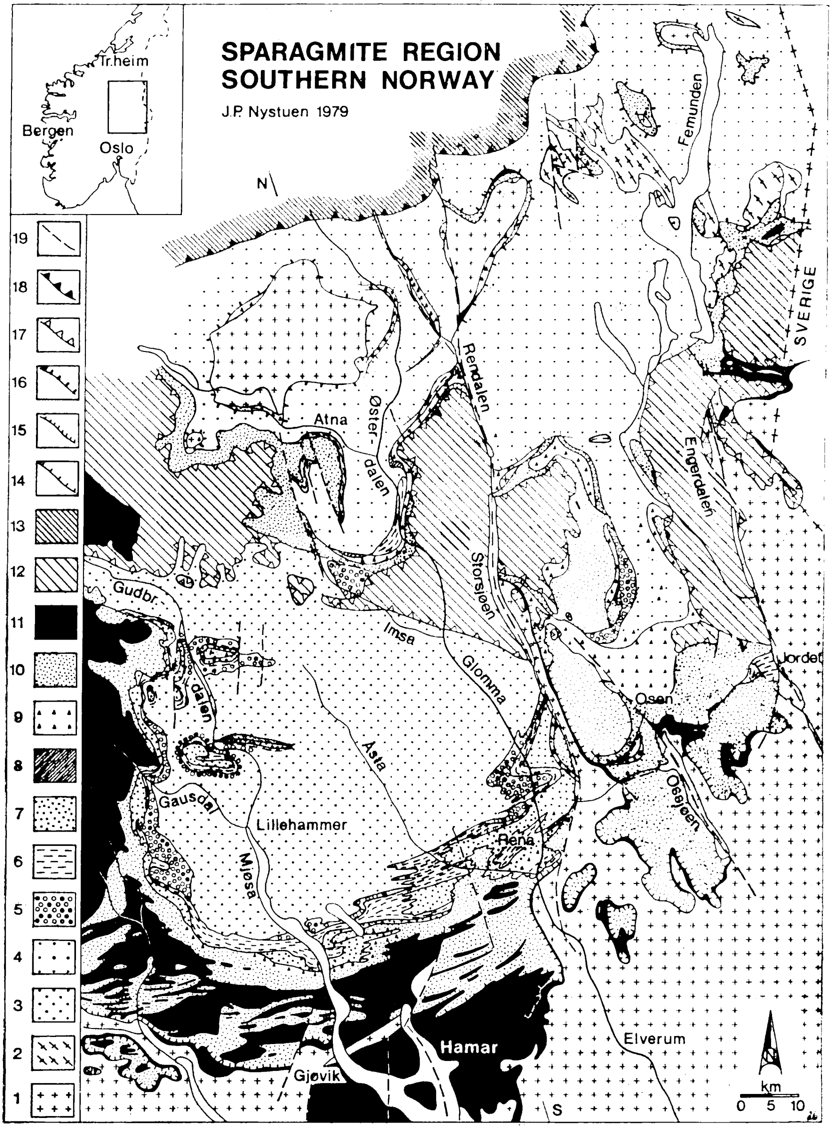

Fig. 2. Geological map of the sparagmite region, southern Norway. Revised data from Englund (1973), Prost (ms), Bjørlykke, Elvsborg, and Høy (1976), and data from the author and Sæther (1979 and personal commun., 1979). 1 = crystalline basement; 2 = Precambrian crystalline rocks in the Røa nappe; 3 = Brøttum Formation; 4 = Rendal Formation; 5 = Biskopås Conglomerate (west of Storsjøen) and Osdal Conglomerate (east of Storsjøen); 6 = Biri, Elta, and Bjørånes Formations; 7 = Ring Formation; 8 = basalt; 9 = Moelv Tillite and Ekre Shale; 10 = Vangsås Formation; 11 = Cambro-Silurian rocks; 12 = Kvitvola nappe; 13 = Trondheim nappe; 14 = thrust plane in general; 15 = Osen nappe thrust plane; 16 = Røa nappe thrust plane; 17 = Kvitvola nappe thrust plane; 18 = Trondheim nappe thrust plane; 19 = normal fault. The letters "N" and "S" indicate the position of the sections in figure 4.

and Osen faults was believed to have divided the main basin into a "western basin" and an "eastern basin." The uppermost sandstone unit, the Vangsås Formation, was thought to have become detached from the underlying Ekre Shale during the Caledonian orogeny and displaced 30 to 50 km toward the south as the *Osen nappe* (previous "Quartz Sandstone nappe"). Transported out of the basin, it lay on a thin veneer of autochthonous Varangian-Ordovician sediments rimming the trough. The remainder of the sequence still in the basin was believed to have suffered folding and minor horizontal displacements (20-30 km, Bjørlykke, Elvsborg, and Høy, 1976) within the basin framework. A pattern of arcuate axial-plane traces within this part of the sequence was explained as the effect of tectonic drag against the basin margins (Holtedahl, 1930). Sandstones thrust above a thin autochthonous unit, which is exposed in several windows in the northern part of the sparagmite region (figs. 1-4), were often interpreted as a nappe (Kvitvola nappe) resting tectonically above the parautochthonous basin-deposited

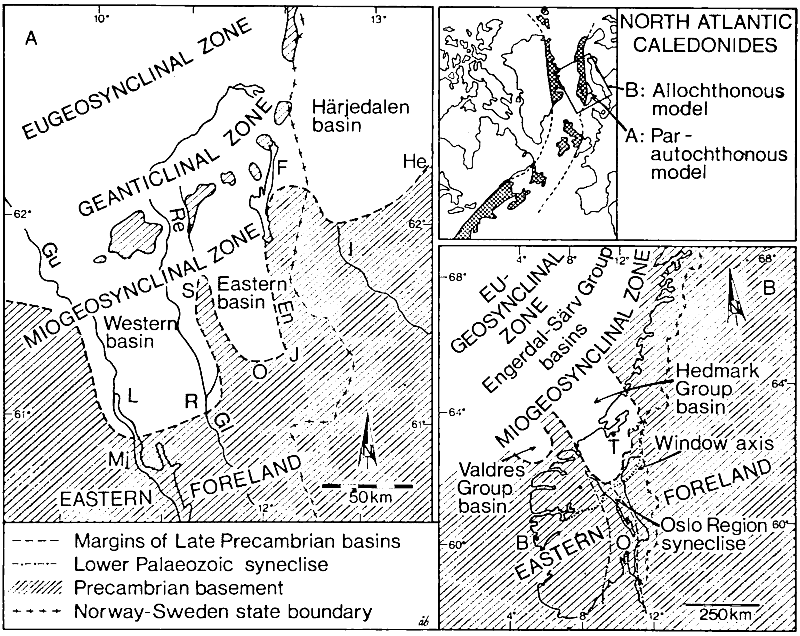

Fig. 3. Paleogeographic positions of Late Precambrian sedimentary basins and Paleozoic sedimentary facies on the western part of the Baltoscandian craton. (A) Paleogeography according to a parautochthonous position of the Hedmark Group ("sparagmites"). En = Engerdalen; F = Femunden; Gl = Glomma; Gu = Gudbrandsdalen; He = Hede; I = Idre; J = Jordet; L = Lillehammer; Mj = Mjøsa; O = Osen; R = Rena; Re = Rendalen; S = Storsjøen. (B). Paleogeography (tentative) according to an allochthonous position of the Hedmark Group ("sparagmites"). Position of Valdres Group (in the Valdres nappe) basin after Hossack (1978), Engerdal Group (in the Kvitvola nappe), and Särv Group (in the Särv nappe) basin approximately after Bjørlykke, Elvsborg, and Høy (1976) and Gee (1978a); Oslo region syneclise partly after Størmer (1967). Several other Late Precambrian basins were located north of the Hedmark Group basin: B = Bergen, O = Oslo, T = Trondheim.

sequence farther south (Strand, 1972). Alternatively the thrust contact was omitted, giving the impression that the basinal sequence was resting autochthonously on the crystalline basement (Bjørlykke, Elvsborg, and Høy, 1976; Bjørlykke, 1978).

Another, much less known *allochthonous basin model* was put forward by Oftedahl (1943a, b, 1949, 1950) (figs. 3 and 4). The sparagmite sequence was interpreted as a giant nappe ("sparagmite nappe") thrust southward from a depositional area lying north of the basement windows. Thrust distances of 300 km were suggested (Oftedahl, 1943a). The main arguments were the observed horizontal shortening of the strata and tectonostratigraphic correspondence between the sequence at the front of the sparagmite region in the south and the sequence in the windows in the north. Nappe models intermediate between the two extreme types were also suggested (Oftedahl, 1954a, b; Holmsen and Oftedahl, 1956), but these also placed the main depositional area for the Hedmark Group north of the windows. Recently, Prost (1977) has suggested a similar intermediate model with basins both on the northern and southern sides of the windows.

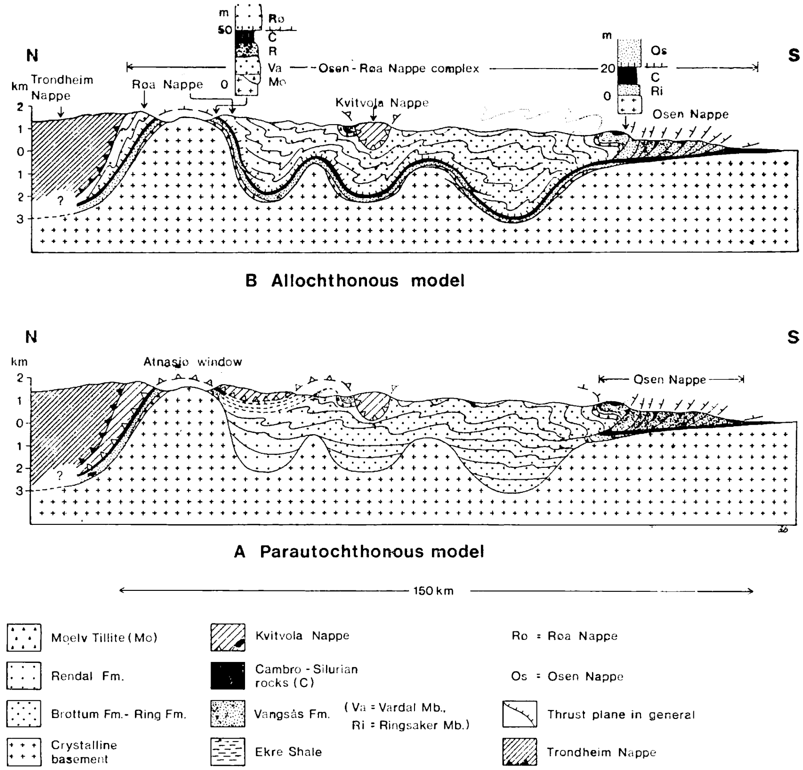

Fig. 4. The principles of the *parautochthonous* and *allochthonous* models of the basin facies Late Precambrian Hedmark Group shown in simplified north-south sections through the sparagmite region. Position of the section is shown by the letters "N" and "S" on figure 2. Depth to crystalline basement is taken from figure 6.

The hypothesis of an allochthonous origin for the thick basin-facies Hedmark Group has been revived by recent mapping in the eastern and northern part of the sparagmite region in Norway (Nystuen, 1974, 1975 a,b,c,d, 1976b, 1978, 1979a,b; Elvsborg and Nystuen, 1978; Sæther, 1979). An allochthonous origin is furthermore strongly favored by the results obtained from studies along the nappe region both in Sweden (Gee, Kumpulainen, and Thelander, 1976, 1978; Gee, 1978a,b; Röshoff, 1978) and in Norway to the west and southwest of the sparagmite region (Hossack and Nickelsen, 1974; Hossack, 1978; Naterstad and Gabrielsen, 1978).

The problem concerning the tectonic position of the basin-facies Hedmark Group and overlying Paleozoic rocks is related to and dependent upon the characteristics and interpretations of a number of features. These include tectonostratigraphy, facies and tectonics of autochthonous strata and the Cambro-Silurian of the Oslo region, facies of thrust Hedmark Group and Paleozoic rocks, provenance of the clast material in the Hedmark Group, basement undulations, regional faults, tectonics of the Osen-Røa nappe complex and its relation to the Valdres and Kvitvola nappes, age of nappe emplacement. These topics are treated below.

TECTONOSTRATIGRAPHY

Autochthonous Precambrian crystalline basement and overlying Varangian to Ordovician sedimentary strata are overthrust by Late Precambrian to Silurian strata forming the *Osen nappe* (A. Bjørlykke, 1973 a, b; Nystuen, 1974) in the southern part of the sparagmite region and as the *Røa nappe* (Törnebohm, 1896; Nystuen, 1975a) around the windows in the northern and northeastern districts (fig. 1). Vemdal and Hede Nappes are names applied respectively to the same tectonic units in Sweden (Röshoff, 1978). The structural relation between the Osen and Røa Nappes is critical for deducing the tectonic position of the basin-facies Hedmark Group rocks, which occur in both units as well as in the area between the exposed thrust contacts of the nappes.

The Osen and Røa nappe units are overlain by middle thrust units such as the *Valdres, Kvitvola, Tännas* (augen gneiss), and *Särv Nappes,* all consisting of subnappes and containing mainly Precambrian metasandstones and sheets of Precambrian crystalline basement rocks. The thrust distances for these middle units are considered to be of the order of 100 to 300 km (Skjeseth, 1963; Englund, 1973; Nystuen, 1975a; Bjørlykke, Elvsborg, and Høy, 1976; Gee, 1978a; Hossack, 1978).

The Valdres Group and the lower part of the overlying Melsenn Group in the Valdres nappe have been correlated with the Hedmark Group in the Osen and Røa nappes (Nickelsen, 1974). Lithology and facies variations of sandstones and conglomerates in the Valdres Group indicate that this sequence, like the Hedmark Group, was deposited in rift-basins or aulacogens within the Baltoscandian craton. The sedimentary rocks of the Kvitvola and Särv nappes, the Engerdal Group (Nystuen, 1974), and the Särv Group (Gee, 1975) are dominated by laterally homogeneous metasandstones with some carbonate beds and a diamictite unit which has been correlated with Late Precambrian tillites in underlying tectonic units (Röshoff, 1975; Bjørlykke, Elvsborg, and Høy, 1976; Gee, 1978b). The paleoenvironment of the Engerdal and Särv Groups was probably one of shelf basins at the margin of the Baltoscandian craton (Bjørlykke, Elvsborg, and Høy, 1976). The Särv Group is penetrated by the Ottfjället dolerite dike swarm, and the intrusion has been correlated with the opening of the Iapetus (Gee, 1975). However, the age of the dolerite dikes is controversial (see Gee, 1978b). Tentative palaeopositions of the Hedmark, Valdres, Engerdal, and Särv Groups according to the allochthonous view are shown in figure 3B. Late Precambrian sedimentary rocks in the Offerdal nappe and in the Jämtlandian nappes of the Swedish Caledonides (Gee, 1975, 1978a,b; Gee, Kumpulainen, and Thelander, 1978) have probably been deposited in fault-bounded basins north of the "Hedmark Group basin."

The uppermost nappe complexes are the *Jotun, Trondheim,* and *Helag nappes,* chiefly composed of high-grade metamorphic Precambrian rocks and eugosynclinal Cambro-Silurian sediments and volcanics. Though a local origin of the Jotun Nappe has been suggested (Banham, Gibbs, and Hopper, 1979; Battey and McRitchie, 1973, 1975; Smithson, Ramberg, and Grønlie, 1974), most geologists presently working in the southern Scandinavian Caledonides consider that all these nappe complexes originated from source areas located west of the present Norwegian coast (for example, Sturt and Thon, 1978a; Gee, 1978a, b; Hossack, 1978, p. 239, fig. 13).

The main tectonic transport of all these nappe units has been toward the east or southeast.

FACIES AND TECTONICS OF AUTOCHTHONOUS STRATA AND THE CAMBRO-SILURIAN OF THE OSLO REGION

The autochthonous sequence exposed along the southern nappe front (figs. 1 and 2) is generally only about 5 to 20 m thick. The oldest known unit is the Varangian Moelv Tillite, which is developed as a basal till facies (Nystuen, 1976a) in depositional contact on the crystalline basement east of the Rendal fault at Storsjøen. The tillite is overlain by the shallow-marine Ringsaker Quartzite Member (Vangsås Formation), which onlaps the basement and thins out southward (Holmsen and Oftedahl, 1956). The onlap sequence is continued southward by fossiliferous Lower Cambrian sandstone and shale and Middle Cambrian dark shale ("alum shale"). The dark shale, continuing into the Tremadocian (Skjeseth, 1963), is usually directly overridden by the Osen nappe, but locally the Arenigian "Orthoceras Limestone" and Llanvirnian-Llandeillian (?) dark shale are also preserved beneath the nappe (Schiøtz, 1902; Holtedahl, 1921).

The autochthonous sequence exposed in the Snødøla, Atnasjø, Spekedalen, Øversjødalen, Tufsingdalen, Steinfjellet, Vigelen, and Sylen windows in the north (figs. 1-3) (Holmsen, 1935; Holmsen and Holmsen, 1950; Oftedahl, 1945; Oftedahl and Holmsen, 1952; Röshoff, 1978; Rui, personal commun., 1978; Nystuen, 1978) ranges in thickness from 2 to 3 m up to about 150 m. Moelv Tillite (basal tillite facies) is locally preserved and is overlain by the Vangsås Formation. The facies of the latter is similar to that in the Mjøsa type area; a lowermost member consisting of fluvial feldspathic sandstone and quartz-conglomerates is succeeded by the orthoquartzite member. Cambrian green and dark phyllite are the topmost units present beneath the overthrust Røa nappe. The higher parts of the sequence have been tectonically disturbed by imbrication, but the horizontal displacement is thought to be inconsiderable.

The correspondence in stratigraphy and facies between the autochthon under the Osen nappe front in the south and that at the windows beneath the Røa nappe in the north strongly implies a continuation of this sequence beneath a nappe cover. Viewed in a regional context the autochthon forms a sequence that onlaps the craton from the north toward the south; such an onlapping sedimentation may have started with deposition of the basin-facies Hedmark Group in an area lying north of the basement windows.

In the Oslo region the thin autochthonous sequence at the southern nappe front is replaced by an epicontinental Cambro-Silurian sequence several hundred meters thick consisting of shale, limestone, and sandstone of eastern foreland facies (Henningsmoen, 1960; Størmer, 1967; Bjørlykke, 1974b). In the Mjøsa area this sequence rests partly on the crystalline basement, partly on the Ringsaker Quartzite Member. Skjeseth (1963) differentiated between an "autochthonous" sequence in the south and an "allochthonous" in the north; the latter is definitely connected stratigraphically to the Hedmark Group of the Osen nappe. Skjeseth (1963) suggested that marked facies differences characterized the assumed "autochthonous" and "allochthonous" sequences. However, facies changes that have to be ascribed to large-scale tectonic separations within the Paleozoic sequence have not been documented by later investigations (Skaar, ms; M. Howe, personal commun., 1978). Tectonic reinterpretations also suggest that the thick Ordovician-Silurian sequence that is folded over a décollement above the autochthonous Cambrian-Tremadocian "alum shale" in the southern Mjøsa district forms a southward continuation of the Osen nappe thrust (A. Bjørlykke, personal commun., 1978).

The Caledonian folding and décollement fades out about 150 km southward in the Oslo region; farther south the strata are unfolded and preserved at their original site of deposition. The folding has been estimated to involve a shortening to less than half the original width across the strike, and hence *the décollement thrust may include a horizontal displacement of about 150 km for the northernmost Paleozoic strata at Mjøsa* (Oftedahl, 1943a; Strand, 1960a). This implies that the intracratonic basin or syneclise of the thick Cambro-Silurian sequence in the Oslo region (Størmer, 1967) must have extended at least 150 km north-northwest of the Mjøsa area. The Hedmark Group basin was very likely located farther to the north as a precursor of the later Paleozoic syneclise (fig. 3B).

FACIES OF THRUST HEDMARK GROUP AND PALEOZOIC ROCKS

Within the Hedmark Group (table 1), some formations (Biskopås, Biri, Ring, Moelv) display lateral facies variations in the Rena–Mjøsa–Gudbrandsdalen area that agree fairly well with the configuration of the hypothetical "western" (or "central") "basin" (fig. 3A) (Skjeseth, 1963; Englund, 1973; Bjørlykke, Elvsborg, and Høy, 1976; Nystuen, 1976a). However, there are some deviations from this pattern.

In the basin models of Bjørlykke (1974a, 1978) and Bjørlykke, Elvsborg, and Høy (1976), the Brøttum Formation (turbidities) is shown to pass from a coarse-clastic marginal facies along both the Rendal fault zone in the east and hypothetical faults west of Gudbrandsdalen into a central shale-dominated facies. Such a central, fine-clastic "plug" cannot be observed. The highest frequency of shale beds locally measured is 35 percent in Gudbrandsdalen, but even in this area sandstones predominate (Englund, 1972, p. 7). Flute and groove casts in the lower, shale-rich part of the formation in Gudbrandsdalen show a paleocurrent direction from west to east (Englund, 1972). However, recent mapping in Østerdalen (Elvsborg and Nystuen, 1978) and in the areas between Østerdalen and Gudbrandsdalen (Englund, 1978; Englund, personal commun., 1979) has demonstrated that the Brøttum Formation in this central part of the "western" basin (fig. 3A) is completely dominated by coarse-grained sandstones with conglomerate interbeds. Petrography and variations in grain size and facies indicate that a coarse turbidite facies has prograded westward far into the basin and above the sandstone-shale assemblage derived from a western source (Englund, personal commun., 1979).

The Biskopås Conglomerate borders on the Rendal fault zone in the Rena area (fig. 2), but in no other areas has the conglomerate been demonstrated to be associated with any fault in the local basement. On the *eastern* side of the Rendal fault, the Osdal Conglomerate is probably a stratigraphical equivalent of the Biskopås Conglomerate (table 1); however, the Osdal Conglomerate is beyond doubt allochthonous within the Osen nappe (Elvsborg and Nystuen, 1978).

The author's own investigations in the eastern and northern part of the sparagmite region (Nystuen, 1974, 1975b,c,d, 1976b, 1978, 1979 a,b; Elvsborg and Nystuen, 1978) have not confirmed the concept of "western" and "eastern" basins bordered by the present Engerdal, Osen, and Rendal fault zones (figs. 1-3). The lack of sedimentological relationship to these faults is well demonstrated by the Rendal Formation (table 1), which extends from Härjedalen in Sweden to west of Glomma. The formation is thrust above the autochthonous beds that crop out east of Storsjøen (Elvsborg and Nystuen, 1978) and within the windows (Oftedahl, *in* Oftedahl and Holmsen, 1952; Nystuen, 1975a, 1978) (fig. 2). East of Femunden the formation is thrust above the Osen nappe (Nystuen, 1975a,b; 1979a,b; Röshoff, 1978) (see below). Within its outcropping area, the Rendal Formation is cut by normal faults without any facies changes. On the other hand, variations in lithofacies, for example, from sandstone to alluvial-fan conglomerate, can be demonstrated to be associated with considerable relief in the allochthonous basement on which the formation rests within the Røa nappe (Nystuen, 1979a).

In contrast to the parautochthonous basin molel, an allochthonous origin for the basin-facies Hedmark Group allows interpretation of the sedimentary evolution of the Hedmark Group in southern Norway within the framework of one major basin (table 1, fig. 5).

The substrata of the Varangian Moelv Tillite exhibit considerable facies variations. The fluvial, arkosic Rendal Formation in the eastern and northern part of the sparagmite region is correlated with the Brøttum Formation (turbidites) in the west (table 1). The Brøttum Formation in lower Østerdalen is a coarse-grained conglomeratic arkose (Bjørlykke, 1966; Bjørlykke, Elvsborg, and Høy, 1976), and its composition is very similar to the Rendal Formation. Red and gray arkoses west of the Rendal fault south of Storsjøen (Elvsborg and Nystuen, 1978) and

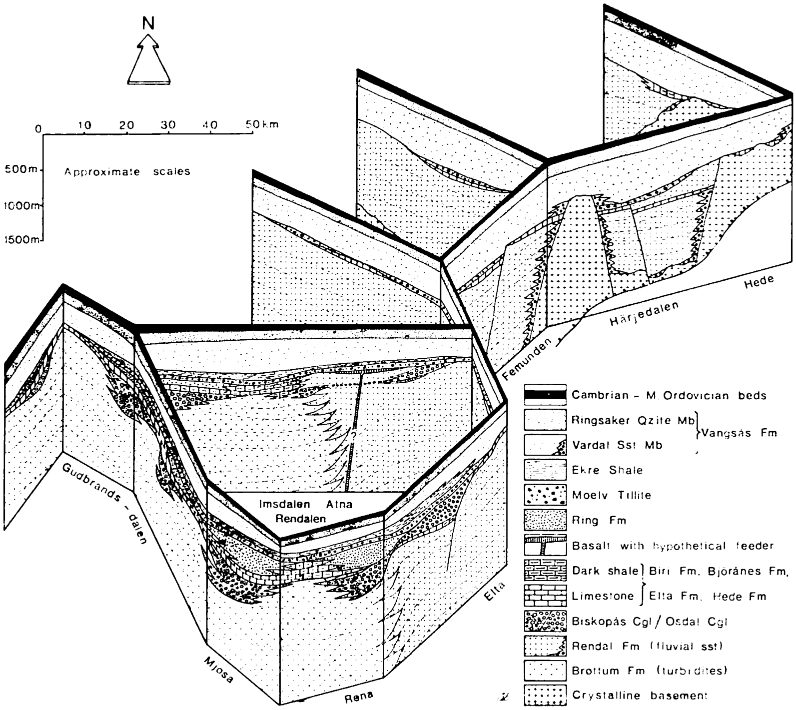

Fig. 5. Fence diagram showing schematically an interpretation of original sedimentary facies relations within the Hedmark Group. An allochthonous position of the basin is indicated by the observed thrust planes beneath the basement rocks in the Femunden–Härjedalen area. Gudbrandsdalen sections from Englund (1972, 1973), Mjøsa–Rena sections from Bjørlykke, Elvsborg, and Høy (1976), Elta–Femunden–W. Härjedalen section from Nystuen (1975a and unpublished), Hede section from Stålhös (1956), and Imsdalen–Atna–Rendalen sections from Sæther (personal commun., 1978) and the author.

similar sandstones west of Glomma and north of Imsa (fig. 2) appear to be transitional facies between the typical Rendal and Brøttum Formations. Recent sedimentological studies by the author in the Rendal Formation have shown that the sedimentary transport was from the east toward the west and suggest that the fluvial arkosic detritus was redistributed by subaquatic mass-flow into the deepest part of the basin and deposited as the coarse Brøttum sandstones in Østerdalen. In the central, northern part of the sparagmite region the fluvial arkoses of the Rendal Formation pass upward and westward into feldspathic quartzites of probable coastal and shallow-marine origin.

The Biskopås Conglomerate in Østerdalen has the same types of lithoclasts as the Osdal Conglomerate east of the Rendal fault (Holmsen and Oftedahl, 1956; Bjørlykke, Elvsborg, and Høy, 1976; Nystuen and Sæther, 1979), and the clast morphology and roundness appear similar. The Biskopås Conglomerate was most likely deposited from submarine mass-flows fed by fluvial drainage systems (Bjørlykke, Elvsborg, and Høy, 1976). The author interprets the Osdal Conglomerate as the fluvial counterpart of the Biskopås Conglomerate in the Rena area and at Imsa farther north (fig. 2). In the area east of Storsjøen the fluvial facies of the Osdal Conglomerate is replaced toward the west by a disorganized conglomerate facies (diamictite), which may have been transitional into the Biskopås Conglomerate.

The Biskopås Conglomerate at Mjøsa, in Gausdal, and in Gudbrandsdalen is considered to have received its material from source areas lying west of the depositional basin (Løberg, 1970; Englund, 1972, 1973; Bjørlykke, Elvsborg, and Høy, 1976).

A pre-Varangian transgression gave rise to deposition of dark shales and limestones belonging to the equivalent Biri, Elta, Bjørånes, and Hede Formations. The Ring Formation represents local subaerial-subaquatic coarse-clastic fans (Bjørlykke, 1978) in the southwestern part of the basin.

The post-Varangian sedimentation was generally more homogeneous throughout the basin and commenced with the postglacial Ekre Shale, probably in response to eustatic rise of sealevel (Nystuen, 1976b). Concomitant and subsequent delta progradation and fluvial sedimentation produced the Vardal Sandstone Member, while the Ringsaker Quartzite Member represents an early Cambrian marine transgression.

Thin flows of *alkali basalt* occur within the Hedmark Group in Østerdalen (Bjørlykke, 1978) and in the Osen area; the latter occurrence is definitely within the Osen nappe. The basalt volcanism was possibly associated with the Late Precambrian rifting of the Baltoscandian-Greenlandian craton. No feeder dikes to these basalt flows have been recognized, and seen in a modern paleogeographical plate-tectonic context (for example, Gee, 1975, 1978a) it is likely that rift-volcanism was located farther west on the Baltoscandian craton than the present position of the basalt.

The sedimentary basin model briefly outlined above is independent of the present faults in the sparagmite region. The sedimentation was tectonically controlled, probably by a complex pattern of faults and basement flexures. A considerable basement relief with depressions and highs was present in pre-Varangian time, and remnants of this paleogeography are preserved in the allochthonous basement sheets within the Røa nappe. Toward the Cambrian the Baltoscandian craton suffered further denudation, resulting in the rather even topographic surface now present beneath the autochthonous sequence at the Osen nappe front and within the windows farther north.

Paleozoic strata rest with sedimentary contact on the Vangsås Formation in the Osen Nappe and within the sparagmite region north of the nappe front. In the Mjøsa area, the Paleozoic rocks in the frontal part of the Osen nappe continue into the Ordovician-Silurian décollement-folded strata of the Oslo Region (A. Bjørlykke, personal commun., 1978).

The Osen nappe Paleozoic rocks can be divided into a southern, *foreland facies* including the sequence at Mjøsa and the outcrops northeastward to Femunden, and a northern *miogeosynclinal facies* comprising the sequence in Gudbrandsdalen and Valdres (fig. 2).

The youngest unit of the southern facies in the eastern part of the sparagmite region is the Llanvirnian-Llandeilian (?) "Ogygiocaris Shale" (Schiøtz, 1902; Holtedahl, 1921), whereas in the Mjøsa area the sequence (above the décollement) ends with the Bruflat Sandstone of upper Llandoverian age (not younger than early Wenlockian) (D. Worsley, personal commun., 1978). Influx of sand, increased chlorite/illite ratio, and unconformities in the sequence have been interpreted as the responses of orogenic episodes in the early Ordovician, late Ordovician-early Silurian, and late Silurian (Størmer, 1967; Bjørlykke, 1974b).

In the Gudbrandsdalen-Valdres area the Middle Cambrian-Tremadocian black shales are overlain by a thick (about 200 m?) sequence of graptolite-bearing phyllites of Llandeilian or early Caradocian age (Bjørlykke, 1905; Strand, 1960b). The phyllite is succeeded by the *Gausdal Formation,* a graywacke interpreted as having originated as turbidites or mudflows during an orogenic event that gave rise to erosion of underlying strata as well as of crystalline basement rocks (Englund, 1973). Englund (1973) suggested a Middle Ordovician age for the Gausdal Formation.

The great contrast between the southern and northern facies of the Cambro-Silurian is very difficult to account for with the parautochthonous sparagmite basin model. Flysch-sedimentation in the present position of the Gausdal Formation is very unlikely, seen in the light of the lateral dimensions presently envoked for the evolutionary history of the Scandinavian Caledonides (for example, Gee, 1978a). However, these sedimentary patterns would be more natural in pre-thrust positions some 150 km or more north or northwest of the strata's present locations.

PROVENANCE OF THE HEDMARK GROUP CLAST MATERIAL

The clast material of the Moelv Tillite in the thrust basinal sequence shows a general similarity to basement rock types presently surrounding the sparagmite region. This feature has been taken as evidence against long-distance thrusting (Nystuen, 1975a; Bjørlykke, Elvsborg, and Høy, 1976).

However, the stone assemblage characterizing the Osdal Conglomerate, Biskopås Conglomerate, and Moelv Tillite in the Glomma-Femunden area (granites, diorites, dolerites, porphyries, red and gray quartzites) may be related to a segment of basement rocks measuring about 150 to 200 km east to west and 400 km north to south, extending northward from about 61° N within the Norway-Sweden border districts (fig. 1) (Nystuen and Sæther, 1979).

Granites, gneisses, quartzites, porphyrites, and anorthosites, rock-types recorded in the conglomerates in the western part of the sparagmite region (Løberg, 1970; Englund, 1972, 1973; Bjørlykke, Elvsborg, and Høy, 1976), could equally well have been present within the Precambrian basement far west on the Baltoscandian craton.

In fact, no clast type of definitely local origin has been recorded. For example, hyperite and magnetite-bearing red gneisses, which are typical of the basement southeast of Rena, have not been observed among the clasts in the Biskopås Conglomerate in the Rena area (R. Otter, personal commun., 1978). Furthermore, the basal till facies Moelv Tillite, which occurs within the basinal sequence in the same area, has only subordinate amounts of granite and gneiss stones (< 2 percent) (Bjørlykke, Elvsborg, and Høy, 1976), although the neighboring basement consists of just these rock types. On the other hand, the *autochthonous* tillite resting on the granite basement east of the Rendal fault contains up to 40 percent of granite fragments (Nystuen and Sæther, 1979).

Critically viewed, the precise, original sedimentation locations on the western part of the Baltoscandian craton of the thrust Hedmark Group are not revealed by the clast assemblages of its conglomerates.

BASEMENT UNDULATIONS

At the southern nappe front the Precambrian basement surface is a very low-relief peneplain (typically < ± 5 m) dipping northward 1° to 2° on average (fig. 1) (calculated from geological maps). The slope steepens at Rena (Bjørlykke, 1976) and Storsjøen (Sæther, 1979), and this flexuring affects overlying autochthonous strata as well as the basal thrust planes of the Osen and Kvitvola Nappes.

The basement windows in the north form the axial culminations of an anticlinal basement ridge that can be followed from the Norway-Sweden state boundary in the northeast to Valdres and Aurland in the southwest. The windows are dome-shaped structures; formational boundaries of the sediment cover and the thrust planes are draped nearly parallel with basement surface (Hossack, 1976; Röshoff, 1978; Nystuen, 1978). The magnitude of the outward dip of the domes varies; thus on the southwestern side of the Atnasjø window it is about 20° to 30°, on the eastern side 40° to 50° and on the southern side of the Spekedal window about 15° to 40°.

Åm's (1976) contour map of depth to magnetic basement in the sparagmite region (fig. 6) is considered to reflect subsurface undulations of the crystalline basement-cover interface. Highs and lows, with the deepest sites about 4000 m below sealevel, are dome- and basin-shaped and are continuous with the window structures in the north and the basement flexures in the south. The downfolding of the Kvitvola Nappe in the area east and west of Storsjøen (figs. 1 and 2) coincides with a structural low in the basement (figs. 4 and 6). The subsurface anomalies may be interpreted as culminations and depressions on basement ridges and troughs arranged *en echelon* and parallel to the partly exposed anticlinal ridge farther north. A common origin for all these basement undulations is very likely.

The basement windows and the steep basement flexures in the south have been interpreted as morphological elements (islands, peninsulas, bays) delimiting a Late Precambrian basin (fig. 3A). The window axis has been thought to have acted as a geanticlinal ridge during the Ordovician and Silurian separating a Caledonian miogeosyncline in the southeast from a eugeosyncline in the northwest (for example, Skjeseth, 1963, p. 90). However, the allochthonous position of the eugeosynclinal rocks within the Trondheim Nappe implies that the border zone between miogeosynclinal and eugeosynclinal facies must have been located much farther west (Størmer, 1967).

Recently, Hossack (1976, p. 28-31) has argued for a pre-thrust origin for the Beito window in the Valdres area (fig. 1) on account of variations in structural thickness and cut-off contacts within the nappe pile draping the window. Similar structures are present within many of the Scandinavian nappe complexes, as for instance in the Røa nappe at Femunden (Nystuen, 1978, and 1979a,b), and they have most likely developed during the nappe translation independently of the basement morphology at the present position of the nappes. Hossack (1976, p. 30) interpreted the tectonic thinning of Cambro-Ordovician phyllites beneath overriding nappes on the northern side of the window (up-movement side) as caused by squeezing of the phyllite against the ridge. Tectonic thinning and squeezing of the autochthonous (or parautochthonous) shale and phyllite sequence is a very common feature beneath the Caledonian nappes along the whole nappe front in Scandinavia. East of the Engerdal fault zone (Nystuen, 1974, 1976b) the shale unit has been virtually removed beneath the nappes, though the basement surface is nearly even and horizontal. On the Spekedal window (Nystuen, 1978), the phyllite is squeezed to zero on the southern, *down-movement side*, whereas it is still present on the northern, up-movement side.

If the basement domes in the windows were topographical highs during the Late Precambrian to Silurian sedimentation, then the autochthonous beds ought to show a marked on lap contact against the domes. This is not the case, and the bending of lithostratigraphical boundaries and thrust planes parallel with basement domes in the windows and the basement flexures farther south strongly support a

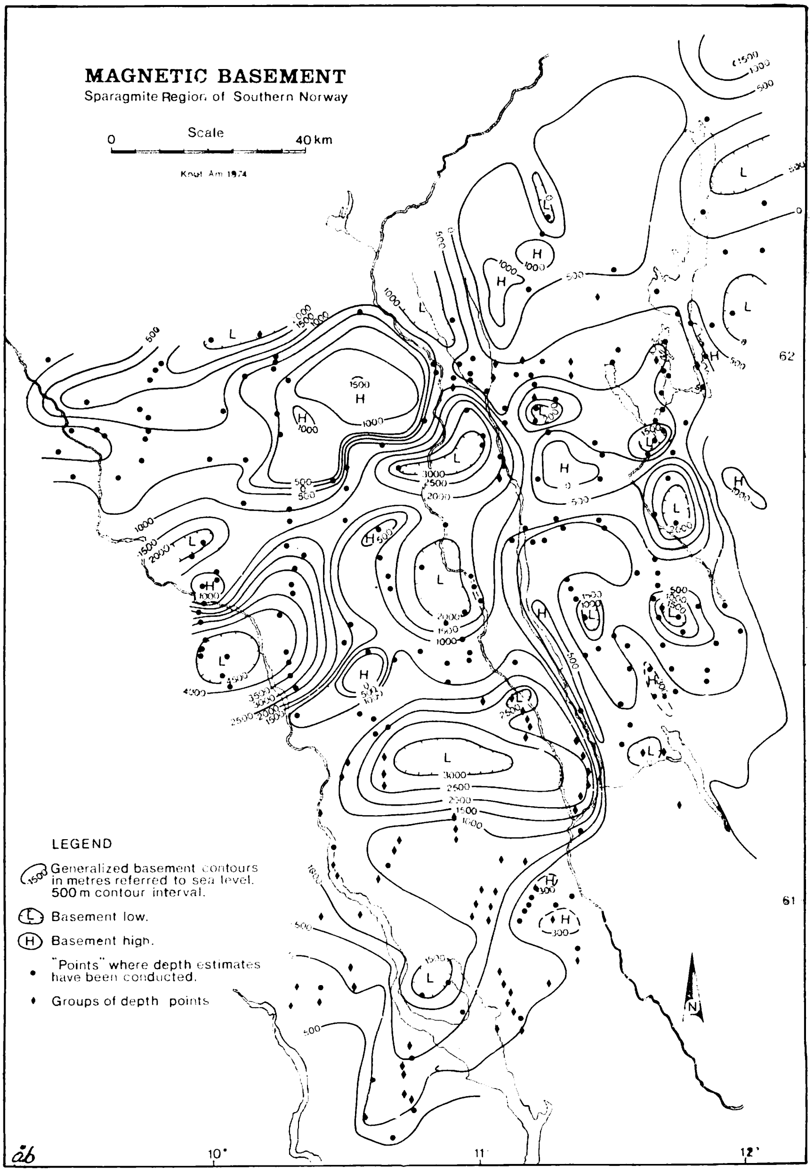

Fig. 6. Map showing depth to magnetic basement in the sparagmite region, southern Norway. The map was constructed by K. Åm and presented at the Nordic Geological winter-meeting 1976 (Åm, 1976).

late- and/or post-Caledonian age for these structures. A similar relative age has also been suggested for basement undulations beneath the Trondheim nappe, and these structures were thought to be linked with the basement antiforms seen in the windows (Grønlie and Rui, 1976). Basement antiforms farther to the north in western Jämtland postdate nappe emplacement (Gee, 1975), and to the southwest, Fareth (1977) arrived at this age relation for basement bucklings in the Aurland area. A late-Caledonian age is also evident for the deep basement depression beneath the Jotun and Trondheim nappes ("Faltungsgraben") and basement undulations below nappes in the Hardangervidda-Ryfylke region (Naterstad, Andresen, and Jorde, 1973). Thrust planes beneath the basement domes have not been reported, and the magnetic anomalies (fig. 6) indicate that the domes are deep-seated structures of the autochthonous basement.

All these basement undulations and those revealed beneath the thrust Hedmark Group in the sparagmite region (fig. 6) are probably interrelated in origin, as complex structures resulting from isostatic adjustments of the crust beneath a nappe cover of varying thickness and density, involving late-Caledonian deep-seated compression and late to post-Caledonian faults. Thus, basement depressions are not restricted to the sparagmite region and cannot be taken as proof of the existence of Late Precambrian sedimentary basins in this particular area.

The deformed basement surface belongs mainly to the Late Precambrian low-relief 'sub-Cambrian peneplain" as seen from the age and facies of overlying autochthonous strata. The pre-Varangian high-relief surface on which the Late Precambrian basin-facies sediments were deposited may be locally preserved within the allochthonous basement sheets in the nappes; such paleorelief is present in the Røa nappe (Nystuen, 1979a,b) and its equivalent, the Hede nappe (Stålhös, 1956; Röshoff, 1978).

REGIONAL FAULTS

The north-northwest-south-southeast running Rendal, Osen, and Engerdal fault zones were fundamental for Schiøtz's (1902, p. 99) original hypothesis of the "sparagmite basin"; he proposed that they had all served as tectonic coast-lines for the Late Precambrian sea.

These faults and several associated smaller ones reveal distinct post- (and/or late-) Caledonian features: they cut the "sub-Cambrian peneplain" and autochthonous sediments and dissect all tectonic structures of the thrust Late Precambrian sediments, crosscutting sedimentary facies. Moreover, during the Caledonian thrust movements a sinistral strike-slip fault seems to have caused a 15 to 20 km displacement within the décollement rocks along the Rendal fault (Skjeseth, 1963). The maximum post-thrust throw on these regional faults can be estimated as at least 1000 to 2000 m (P. Holmsen *in* Holmsen and Holmsen, 1950; P. Holmsen *in* Holmsen and Oftedahl, 1956; Nystuen, ms). These values approximate depths to magnetic basement along the faults (fig. 6).

Along the Engerdal and Rendal fault zones there is evidence of Precambrian tectonic episodes (recrystallized, fractured mylonites, several generations of quartz veins). However, features of recurrent activity are also very common along major faults cutting the Precambrian crystalline basement elsewhere in southern Norway.

A Permian age, as for the Oslo rift farther south, is generally suggested for the last activation of the normal faults in the Sparagmite region. Their parallelism with fracture zones in the Precambrian bedrock in surrounding areas (Ramberg and others, 1977) and their indications of being old lines of tectonic weakness are not *evidence* that deep troughs were formed between them at the end of the Precambrian.

TECTONICS OF THE OSEN-RØA NAPPE COMPLEX AND ITS RELATION TO THE VALDRES AND KVITVOLA NAPPES

In the south the Osen nappe is dominated by the Vangsås Formation and overlying Cambro-Silurian rocks of the southern, foreland facies, but northward older units also occur above the basal thrust plane. This is well demonstrated along the deep embayment in the nappe front along the Rendal fault; all stratigraphical units of the Hedmark Group, from the Rendal Formation up, are present within the nappe close to its westward-facing escarpment. Small slices of the original granite basement are also included here in the nappe sequence (Sæther, 1979). The 70-km distance from the erosional nappe front at Elverum to the northernmost locality where the thrust plane is exposed above the autochthon east of Storsjøen gives a minimum value for the horizontal displacement.

About 50 to 70 km farther north, a thrust contact, equivalent to that beneath the Osen nappe, is present below the Rendal Formation within the window region. A mylonite or phyllonite zone about 10 to 30 m thick separates the nappe from the autochthonous sequence below. The nappe also includes sheets, slices, and subnappes of crystalline Precambrian rocks (granite, augen-granite, augen-gneiss, blastomylonites, diorites). Depositional contact is well preserved between these allochthonous crystalline rocks and the Rendal Formation both east and west of lake Femunden.

This *Røa nappe* (or nappe complex) continues eastward into Härjedalen in Sweden and, east of lake Femunden, lies upon the Osen (Vemdal) nappe (Nystuen, 1975a, 1979a,b; Röshoff, 1978). Red, fluvial (braided river) arkoses and conglomerates, identical to those occurring in the Røa nappe east of Femunden, are also present west of the lake and extend several tens of kilometers to the south, merging into the Osen nappe structure at Storsjøen and Ossjøen. *Thus, the Osen and Røa nappes appear to be joined into one giant nappe complex west of lake Femunden and the Engerdal fault, and a major basal thrust plane supposedly exists beneath the Hedmark Group rocks from the Osen nappe front in the south to the Røa nappe in the north.* The minimum thrust distance of this *Osen-Røa Nappe complex* must consequently be extended to about

140 to 170 km. This minimum thrust distance must be extended to compensate for internal shortening caused by folding, imbrication, low-angle thrusting, and stretching. This quantity can tentatively be estimated to be of the order of 100 to 200 km. The total nappe displacement may amount to 200 or 400 km.

With the Osen-Røa nappe complex relative displacement took place by folding, high-angle imbrication, and low-angle thrusting. West of Mjøsa the nappe complex is divided into two subnappes by a nearly horizontal thrust plane (Strand, 1954; Hossack, 1978).

The fold pattern within the Osen-Røa nappe complex is characterized by folds with arcuate hinges, convex to the southeast, and with axial planes dipping to the northeast, north, and northwest. This fold style is recognizable on a regional scale (fig. 7) as well as in single outcrops. In the Valdres area similar structure also occurs within the overlying Valdres nappe, and Nickelsen (1974, p. 88) favored the interpretation that it formed during rotation of originally northeast-southwest trending F_1 folds toward the longest axis of the deformation ellipsoid (northwest-southeast). Penetrative S_2 slaty cleavage and L_2 elongation lineation (northwest-southeast) were found associated with this D_2 phase of stretching and flattening in the Valdres nappe as well as in the Osen nappe beneath. Hossack (1978) referred the cleavage/schistosity formation and the origin of pebble deformation in the Valdres nappe to a second phase of deformation connected with a flattening beneath the Jotun nappe.

The structural relation between the Osen-Røa nappe complex and the Kvitvola nappe is complicated. The interface truncates the arcuate fold pattern (fig. 7), and the Kvitvola nappe rests on units ranging from

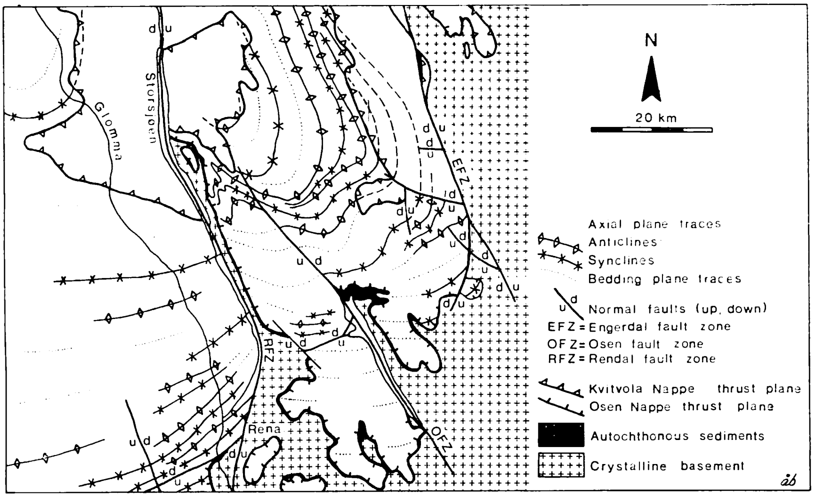

Fig. 7. Traces of axial and bedding planes in thrust Hedmark Group rocks and of post-Caledonian normal faults in the southeastern part of the sparagmite region, southern Norway.

the Rendal and Brøttum Formations to Ordovician strata. A severe deformation (phyllonites) characterizes the thrust zone of the Kvitvola nappe, but in the underlying rocks clastic texture is preserved close (20-50 cm) to the thrust contact.

The Kvitvola nappe sandstones are characterized by a plastic fold style of isoclinal mesofolds (F_1), mineral elongation (L_1), and slaty cleavage (S_1). The lineation lies within the penetrative slaty cleavage, which is coincident with F_1 axial planes; the S_1 foliation normally parallels the basal thrust plane. F_1 folds and L_1 lineations trend 140° ± 20°. Pre-F_1 folds and associated foliation may be present in Gudbrandsdalen (D_1 structures of Englund, 1973).

The Osen-Røa nappe rocks in the southern and southeastern part (fig. 7) of the sparagmite region are influenced by a brittle type of deformation (imbrications, cataclasis, joints, local fracture cleavage). Pebbles are deformed by flattening only in zones of high shear parallel to local bedding or axial planes (Nystuen, 1976a). There is no penetrative foliation and elongation lineation corresponding to the structures in the Kvitvola nappe.

Deformation by flattening increases toward the north in the Osen-Røa nappe rocks, and in the window region cleavage and elongation lineations (northwest-southeast) are developed, primarily in shear zones parallel to bedding planes in the Gudbrandsdalen area. This type of lineation has the same orientation, about 110° to 130°, as large- and small-scale folds belonging to the regional arcuate fold pattern in the Osen-Røa nappe complex (D_2-structures of Englund, 1973). A penetrative fracture/slaty cleavage (east-northeast-west-southwest, dipping north) in Gudbrandsdalen (D_2 cleavage of Englund, 1973) is either contemporaneous with the elongation, or younger.

The Osen-Røa nappe complex and the Kvitvola nappe are both affected by broad regional folds (D_2 folds of Englund, 1973, p. 35-36). The fold axes are orientated about 130° in Gudbrandsdalen and 100° in the central part of Østerdalen, while east of Storsjøen the folds trend 160° in the west and 80° to 50° in the east. Thus, these folds also probably display arcuate fold axes.

Large-scale folds and upthrusts with axial and shear planes striking northeast-southwest and dipping north represent the youngest Caledonian deformation phase in the sparagmite region. This phase has affected the Osen-Røa rocks and the Kvitvola nappe thrust plane in the Storsjøen-Glomma area and at Femunden (Holmsen, 1935; Holmsen and Oftedahl, 1956; Strand, 1972). A fracture cleavage (east-northeast-west-southwest, dipping north) is associated with this late deformation.

The arcuate fold pattern of the Osen-Røa nappe complex is interpreted by the author to have formed during one phase of deformation. Nickelsen (1974, p. 88) also discussed this possibility for the similar fold geometry in the Valdres nappe. Very similar structures form within highly viscous, flowing bodies such as glaciers, lavas, land-slides, and debris flows (for example, Hansen, 1971). It is suggested that Osen-Røa nappe structures developed continuously within a décollement nappe driven by gravity. By increasing friction in the cool periphery of the nappe, compressional structures such as overturned and isoclinal folds, high-angle thrusts, and imbrications were produced. In the more northerly and northwesterly parts of the nappe, stretching and flattening were more severe under the overburden of a thicker nappe pile, and cleavage and elongation lineation were formed.

The discordant contact between the Osen-Røa nappe complex and the Kvitvola nappe must be due either to tectonic truncation or to erosion prior to emplacement of the Kvitvola nappe. The plastic folds and the associated slaty cleavage and lineation in the Kvitvola nappe are evidently *early structures* in the nappe's history, and they must have been formed in tectonic settings of higher temperature-pressure conditions than those in which the underlying Osen-Røa rocks were deformed. The flattening and stretching of the Kvitvola nappe rocks may have been produced by gravity collapse of a thick and dense nappe pile, as proposed for other Caledonian nappes in Scandinavia (Hossack, 1968; Gee, 1977, 1978a; Ramberg, 1977). It is the author's opinion that this plastic type of deformation must predate the latest movement of the Kvitvola nappe when it became joined with the Osen-Røa nappe complex.

It has been suggested that the Valdres and Kvitvola nappes are tectonically equivalent units (Englund, 1973; Nickelsen, 1974). However, as also pointed out by Englund (1973, p. 54), the correlation is very uncertain. Hitherto, the nappes have not been reported to pass into each other, and judged from the different stratigraphy and facies of their sedimentary units a correlation appears unlikely. On the other hand, a greater correspondence exists in stratigraphy and sedimentary facies between the Late Precambrian rocks in the Valdres and Osen-Røa nappes. An original proximity of the Valdres and Hedmark Group basins (Hossack, 1978) may account for this similarity and the high degree of structural conformity between their derived nappes. A more distant origin of the Kvitvola nappe (Bjørlykke, Elvsborg, and Høy, 1976) and the Särv nappe (fig. 3B) may explain the greater structural deviation between this nappe and the underlying Osen-Røa nappe complex.

AGE OF NAPPE EMPLACEMENT

The main phase of nappe emplacement in the central and southern Caledonides of Scandinavia has been referred to the Scandian (or Scandinavian) orogeny of Middle Silurian to early Devonian age (Gee, 1975; Sturt, 1978).

Pre-Ashgillian events of nappe translation, deformation, regional metamorphism, intrusion, uplift, and erosion have also been recorded within the eugeosynclinal facies rocks in western Norway (Naterstad, 1976; Sturt and Thon, 1976, 1978b). Orogenic movements of this age may be related to the Ordovician contraction phase of the Iapetus Ocean (Roberts and Gale, 1978; Spjeldnaes, 1978).

Ordovician crustal instability is also demonstrated by the miogeosynclinal facies sediments in the Osen-Røa nappe complex and probably also within the Oslo Region décollement unit (Stømer, 1967). The Middle to Upper Ordovician (?) Gausdal *(turbidite)* Formation has received detritus from crystalline rocks similar to those in the Jotun nappe (Englund, 1973), and the origin of this flysch unit may herald the appearance of the Jotun nappe within the miogeosynclinal zone. The Norråker Formation of graywackes (turbidites) in the Jämtlandian nappes (Gee and others, 1974) may also be related to Ordovician compressional movements set up by nappe detachments and not only by the vertical rise of a geanticlinal ridge as indicated by Gee (1975, p. 503).

"Jotun-perthite" grains in Llandoverian-Ludlovian sandstones in the Oslo region have also been attributed to erosion from the advancing crystalline nappes (Jotun nappe) (Strand, 1960b; Bjørlykke, 1974b; Turner and Whitaker, 1976).

The early tectonic history of the Kvitvola, Valdres, and Osen-Røa nappes (Gee and others, 1974) may also be related to Ordovician compressional movements set up by nappe detachments and not only by the vertical rise of a geanticlinal ridge as indicated by Gee (1975, p. 503).

CONCLUSIONS

Tectonic structures, stratigraphy, and sedimentary facies of the basin-deposited classical "sparagmites" (Hedmark Group) and overlying Paleozoic strata in southern Norway and adjacent parts of Sweden are most satisfactorily explained by an allochthonous model including a horizontal displacement of the Osen-Røa nappe complex for 200 to 400 km toward the south or southeast. The Cambro-Silurian décollement unit in the Oslo Region is considered to be the southward continuation of the thrust. An allochthonous origin is in accordance with similar allochthony of the Late Precambrian-Silurian rocks at the Caledonian front in Västerbotten-Jämtland in Sweden (Gee, 1975; Gee, Kumpulainen, and Thelander, 1978; Röshoff, 1978). The Osen-Røa nappe complex thus forms the "missing link" in a continuous series of apparently rootless nappes wedging laterally into each other along the whole eastern belt of the Scandinavian Caledonides.

The evolution of the Osen-Røa nappe complex is believed to have included the following main events:

1. During the initial rifting phase of the Iapetus Ocean a thick sequence of Late Precambrian sediments (Hedmark Group) was deposited within the present Møre-Trondheim region or farther west. A transgression, starting at the end of Precambrian (Vendian) time, gave rise to an epicontinental sequence lapping onto the denuded Baltoscandian craton to the east and southeast. The thick, lower Paleozoic sequence of the Oslo region was deposited in an elongated basin (syneclise) forming a southeasterly continuation of the Late Precambrian basin.

2. The initial detachment and deformation of the Osen-Røa nappe and the overlying Valdres and Kvitvola nappes were related to the upthrust and advance of the Jotun nappe and its equivalents. This

phase may be reflected by the Middle to Upper Ordovician (?) Gausdal (turbidite) Formation within the Osen-Røa nappe complex.

3. During the final contraction phase of the Iapetus Ocean in Middle Silurian-early Devonian (Scandian orogeny) the Osen-Røa nappe complex was emplaced at its present position as a gravity-moved décollement. The thrusting continued southward by décollement folding of the Cambro-Silurian within the Oslo-region syneclise. Adjacent nappes of middle and higher structural positions were emplaced during this phase and suffered late thrust deformation, along with the Osen-Røa nappe complex. The Valdres and Kvitvola nappes were derived from different positions within the orogen, explaining the different structural contacts of these nappes with the underlying Osen-Røa Nappe complex.

4. Late Caledonian (Lower-Upper Devonian?) isostatic adjustments and horizontal compression affected basement, autochthonous sediments, and nappe cover to produce a series of northeast-southwest elongated ridges, depressions, domes, and basins. Normal faulting was locally associated with basement flexuring due to tensional relaxation in the crust.

5. Late (?) to post-Caledonian (Permian) subsidence along north-south and north-northwest-south-southeast trending faults increased the basin-like form of the present sparagmite region.

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