THE STOKKVOLA CONGLOMERATE – A REVISED STRATIGRAPHICAL POSITION

DAVID ROBERTS

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Detailed mapping has shown that the Forbordfjell greenstone is a distinctive volcanic formation occurring actually within the Lower Hovin Group of the Trondheim Supergroup, and is therefore not a Støren Group correlative as previously supposed. The Stokkvola conglomerate, lying stratigraphically above the Forbordfjell greenstone, is accordingly a good deal younger than has been considered in the past, probably of Llandeilian age. Moreover, the pararogenic movements which led to the deposition of this conglomerate clearly cannot be equated with the Trondheim disturbance. Some consequences of this revised stratigraphy are discussed briefly with reference to the local and regional lithostratigraphical sequences and to the palaeontological evidence.

D. Roberts, Norges Geologiske Undersøkelse, Postboks 3006, 7001 Trondheim, Norway.

An important and useful marker horizon in the Lower Palaeozoic sequence of the Trondheim Region is that represented by the informally termed 'greenstone conglomerate' (Holtedahl 1920, H. Carstens 1960), which in several areas lies directly upon the thick, basaltic greenstone-dominated Støren Group. Various local names have been used for this particular lithology, the most familiar synonym in the literature perhaps being the *Stokkvola conglomerate* (Vogt 1928, Strand 1960, 1972), itself deriving from Tørnebohm's (1896) designation 'Stokvola breccie'. Equally well known is the name *Venna conglomerate* from the classical Hølonda–Horg area (Vogt 1945), while the *Lille Fundsjø conglomerate* (Chaloupsky & Fediuk 1967, Wolff 1967) represents a similar niveau in eastern districts.

The stratigraphy above this greenstone conglomerate horizon, embracing the Lower and Upper Hovin and Horg Groups and correlatives, has been described in several of the papers cited above and also reviewed by Roberts et al. (1970). In addition, the high-rank term Trondheim Supergroup has recently been introduced by Gale & Roberts (1974) for the complete lower Palaeozoic succession of the Trondheim Region.

During the course of a gradual extension of detailed mapping and tectonic studies started in 1965-66 in a central part of the Trondheim Region (Roberts 1967a), the author has traversed the prominent ridge Stokkvola which provided the name for Tørnebohm's (1896) greenstone breccia (though spelt 'Stokvola' in Tørnebohm's day).

The Stokkvola conglomerate, in the type area, lies stratigraphically above a greenstone or greenschist which has generally been alleged to represent an overfolded segment of the Støren Group (H. Carstens 1960, Strand

1972). Before re-mapping the area, the present author accepted this interpretation and the available maps in formulating the major tectonic structural picture of this particular part of the region (Roberts 1968). As work progressed, however, it gradually became clear that this volcanic sequence, which reaches its maximum extent on Forbordfjell some few kilometres to the south-west of Stokkvola (Fig. 1), does not appear to equate with the Støren Group greenstones. It is, indeed, representative of a younger volcanic horizon. In view of these findings, which necessitate a reassessment of accepted notions, not least where palaeotectonics and the Stokkvola conglomerate are concerned, it is timely to present an outline of the mapping results and their implications. Full lithological details will be given in map-sheet descriptions and therefore only the main features are presented here.

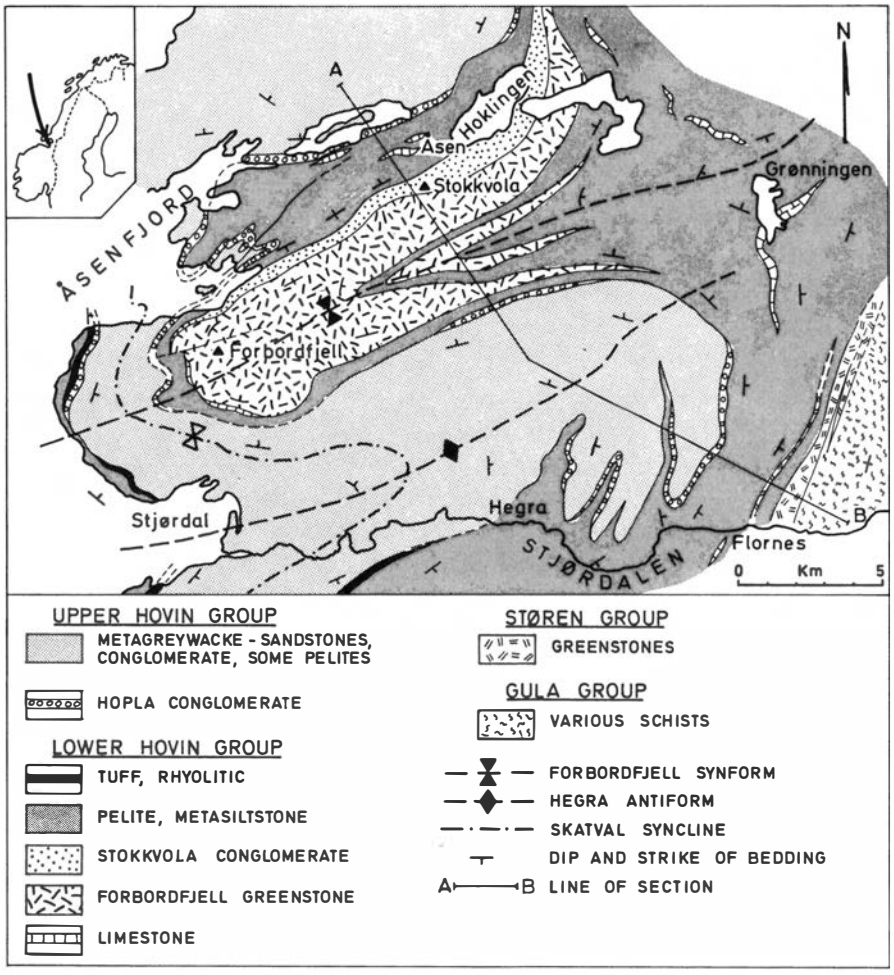

Fig. 1. General geology of the Stokkvola–Hegra area. The stratigraphy is here much simplified, showing only the principal lithologies. More lithostratigraphical detail is presented in Table 1.

General geology of the Stokkvola–Hegra area

Four of the five principal lithostratigraphic units or groups which constitute the Lower Palaeozoic Trondheim Supergroup are represented in this particular area; these are the Gula, Støren, Lower Hovin and Upper Hovin Groups. Within the confines of the map (Fig. 1) and as far as the subject-matter of this paper is concerned, the Gula and Støren Groups are of little consequence. For the record, the Gula is composed mainly of locally strongly tectonized, garnetiferous or hornblendic schists with some quartz phyllites, and the Støren Group of greenstones and greenschists. Their contact is of an intricate tectonic character (Roberts 1967a:102, Gale & Roberts 1974).

Disregarding for a moment the evidence provided by the Forbordfjell greenstone and Stokkvola conglomerate formations, the Lower Hovin Group shows a considerable variation in lithology. Although fairly low-grade phyllite and banded semi-pelitic rock-types predominate, there are several limestone and metagraywacke-sandstone units which often display rapid, lateral, primary facies changes. Minor greenschists and acidic tuff horizons and thin greenstone layers are also present. The distinctive basal greenstone conglomerate, represented in neighbouring districts, is not developed within the area of Fig. 1.

The Upper Hovin Group, which commences with a polymict conglomerate, the Hopla conglomerate, is by and large a turbiditic psammitic succession with thick metagraywackes and frequent intercalations of polymict conglomerate or pebbly sediments. Subordinate lithologies include pelites, thin limestones and silicic tuffs. The sedimentary characteristics and depositional environment of the Upper Hovin Group in the Trondheimsfjord area have been described by Roberts (1968, 1969, 1972).

Structurally, the Stokkvola–Hegra area is dominated by two major, open folds, the Forbordfjell synform and the Hegra antiform (Roberts 1968). These are responsible for the general strike and outcrop pattern (Fig. 1) and are depicted in Fig. 2. Abundant primary sedimentary structures throughout the area show that these folds are deforming an inverted stratigraphy; they also deform the penetrative schistosity which was developed axial planar to

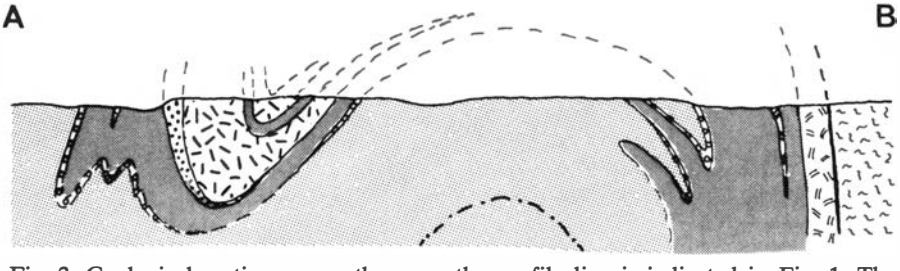

Fig. 2. Geological section across the area; the profile line is indicated in Fig. 1. The ornament is also the same as that in Fig. 1.

earlier tight to isoclinal folds. The present area is, in fact, situated largely on the inverted limb of a major, NW-facing, early (F1) recumbent syncline, the Skatval syncline of the present author (Roberts 1968). This is a flanking synclinal structure to the major Stjørdalen anticline further east which contains the Gula Group in its core. The discovery that the Forbordfjell greenstone is younger than the Støren Group greenstone lavas does not influence the regional structural interpretation to any significant extent.

Against this stratigraphical and structural background we can now consider the character and relationships of the Stokkvola conglomerate and Forbordfjell greenstone. The *Stokkvola conglomerate* is a green-coloured, poorly sorted, polymict lithology with a primary stratification depicted by particular size-ranges and packing of its pebbles and cobbles (Fig. 3). The matrix is a grey-green silty psammite, locally very coarse and of graywacke character near the base of the formation and becoming more phyllitic in aspect higher up. Extreme lateral and vertical variation in pebble size is a common feature, even on outcrop scale; coarse cobble conglomerate may give way within metres to a granule conglomerate. Greenstone of varying type and grain-size constitutes the principal pebble material, but other rock-types are numerous and well represented: jasper, tuffs, quartz keratophyre, limestone, siltstone, graywacke-sandstone, pelites, quartzites, trondhjemite and related acid intrusives, and subordinate gabbro.

Fig. 3. The Stokkvola conglomerate exposed on an ice-smoothed surface in a gravel-pit 0.5 km south of the SW end of Hoklingen. Note the variety of pebble shape and degree of roundness (subrounded to angular), and the poor sorting. The matrix is largely a green-grey silty psammite. A gritty layer is present below the hammer-head. The exposed surface is approximately normal to a weak pebble elongation lineation.

Fig. 4. A facies of the Stokkvola conglomerate showing a variety of pebble and cobble size and shape, and a comparatively high clast/matrix ratio. Locality along timber track 1.4 km NNE of Forbordfjell.

Cobbles of greenstone and jasper occasionally measure up to 30 cm, rarely 40 cm across, though most are $\leq$ 10 cm. These larger fragments are generally subangular. This feature, and the fact that fragments of quartz keratophyre, various tuffs and some siltstone may be quite angular and platy (Fig. 4) no doubt influenced Tørnebohm's (1896) designating the lithology as a breccia. Overall, however, conglomerate is the appropriate term. Between Stokkvola and Hoklingen where the formation attains its maximum thickness, approximately 800 m, a large proportion of the lithology is indeed more of a pebbly metasediment with low pebble/matrix ratios.

To the south-west the conglomerate gradually thins out (Fig. 1) and at the same time the pebble size diminishes, clearly indicating a primary facies change. Much the same development is found to the north outside the map-area. A general decrease in pebble size and packing is also observed near the upper boundary of the conglomerate.

Throughout its outcrop, the Stokkvola conglomerate shows a comparatively weak tectonic deformation depicted mostly by pebble elongation, and then chiefly by the smaller pebbles. Interesting changes in the bulk strain have been recorded, maxima seemingly related to shear zones. Observations have shown that the principal pebble elongation, which varies in trend across the area, was achieved prior to the development of the Forbordfjell synform, during the F1 deformation episode.

Stratigraphically below the conglomerate between Forbordfjell and Stokkvola is a fairly massive, weakly foliated greenstone; in a few horizons this displays pillow structure. Intercalated within the greenstone are subordinate layers of quartz keratophyre, agglomerate and finer-grained greenschist. Tracing this *Forbordfjell greenstone* along the strike along both limbs of the Forbordfjell synform, one finds that the greenstone becomes progressively finer grained, changing in fact into a greenschist. At the same time thin intercalations of green-grey tuffaceous sediment appear, often showing graded bedding. The southern limb of the synform, east of Forbordfjell summit, is particularly instructive in this respect. Ultimately, the volcanic greenschist is replaced laterally by a green-grey phyllite or phyllite-siltstone alternation; some coarser-grained calcareous sandstone layers are also present. Moving further eastwards and then south-eastwards along the strike around the Hegra antiform, the green coloration in these metasediments gradually gives way to a general grey colour. These predominantly grey phyllitic rocks constitute the bulk of the typical Lower Hovin sequence in the Stjørdalen profile in the Flornes area.

It is thus possible to follow Lower Hovin sediments north and north-westwards from Flornes and observe the gradual colour changes and incoming of volcanic tuffaceous material until distinctive greenstone lavas with some agglomerate are encountered on Forbordfjell. The primary nature of these changes is indisputable.

Stratigraphically below (now structurally above) the greenstone–greenschist formation in the core of the Forbordfjell synform is a sequence of grey to green–grey phyllites, siltstones, calcareous sandstones, thin quartzites and some keratophyre bands, as well as limestone in the Grønningen–Movatn area. Again, these lithologies clearly belong to the Lower Hovin succession (Fig. 1), and can be traced northwards into the Skogn–Levanger district.

In the Forbordfjell area, a limestone and a phyllitic shale/siltstone sequence with minor rhyolite tuff occurs stratigraphically above the greenstone, but below the Upper Hovin; the greenstone boundary here is a tectonically disturbed unconformity. Further north-east, in the Stokkvola–Åsen district, similar lithologies are encountered, additionally with thin conglomerate layers, below the Upper Hovin rocks. To the north, outside the map-area near Skogn, these uppermost Lower Hovin lithologies thin out rapidly such that the basal Upper Hovin Hopla conglomerate lies almost directly upon an also thin, gravelly, Stokkvola conglomerate.

It is therefore clear that the Stokkvola conglomerate and the Forbordfjell greenstone constitute formations occurring actually within the Lower Hovin Group (Table 1), and do not represent basal Lower Hovin greenstone conglomerate and Støren Group lavas, respectively, as previously supposed. Interestingly, this positioning of the Forbordfjell greenstone within what is now termed the Lower Hovin Group was advocated by C. W. Carstens (1920) in his detailed memoir on the Trondheim Region, yet the proposal has never even been mentioned by later writers.

The revised stratigraphy also demonstrates that not a great deal of reliance may be placed on inter-regional conglomerate correlation, particularly where fossil control is minimal. Rapid litho-facies changes and local unconformities would be the rule in this much tectonically disturbed depositional environment related to the developing island-arc complex (Gale & Roberts 1972, 1974), and these complexities can be revealed only by careful mapping and field observation.

Regional considerations

That the Stokkvola conglomerate is younger than has generally been assumed has repercussions for several aspects of the regional stratigraphy and tectonics. Similarly, the revised position of the Forbordfjell greenstone permits a re-comparison with the volcanic parts of stratigraphies erected in neighbouring districts (Table 1).

Some few kilometres to the south-east of the city of Trondheim, a greenstone horizon occurring at Jonsvatn was recognised by C. W. Carstens (1920) as representing a volcanic period within his 'Hovind Group' (now Lower Hovin). Moreover, Carstens noted the local presence of a conglomerate of greenstone detritus on top of this unit. The Jonsvatn greenstone would thus appear to correlate fairly readily with the Forbordfjell greenstone. Oftedahl (1974) has also noted the mid-Lower Hovin position of the Jonsvatn greenstone and its extension further to the south-west, and suggested it to be a stratigraphic equivalent of the Hølonda andesite (Vogt 1945).

In the extreme north-western part of the Trondheim Region, between Steinkjer and Snåsa, the Lower Hovin Group takes on a different character with limestone, greenstone and greenschist as the predominant lithologies (Peacey 1964, Roberts 1967b). A thin greenstone unit occurs in the middle of the Lower Hovin sequence near Steinkjer (H. Carstens 1960), whereas around Snåsa, some 60 km to the north-east, schistose greenstones make up the bulk of the succession (Roberts 1967b). These extend into the Grong area.

Linking this local stratigraphy to the situation in the Forbordfjell area is none too easy. A lack of detailed mapping is the main reason, but from the author's work as far north as Levanger and Ytterøy it is clear that the Forbordfjell greenstone can be traced into this district. At the same time the Stokkvola conglomerate thins rapidly into a gravelly, green-grey, silty phyllite. Quite possibly the thin mid-Lower Hovin greenstone at Steinkjer may be followed southwards across Inderøy onto the island of Ytterøy.

Correlating across into the eastern part of the Trondheim Region, in the Meråker–Færen district a greenstone horizon is present at the top of the Lower Hovin equivalent, the Sulåmo Group (Wolff 1967, Chaloupsky & Fediuk 1967). This is almost certainly a correlative of the rhyolitic and intermediate tuffs which occur fairly extensively at the top of the Lower Hovin in the Stjørdal–Forbordfjell district. Occurring actually within the Sulåmo Group on the 1 : 50 000 map-sheet Færen (Wolff 1973) is a thin greenschist unit,

Table 1. Stratigraphic correlation within the Trondheim Supergroup based on the revised succession in the Stokkvola–Hegra area. (Local group names italicized)

Main groups	Stokkvola–Hegra–Stjørdal area (this paper)	Jonsvatn–Hølonda–Horg arca (C. W. Carstens 1920, Vogt 1945, Chaloupsky 1970)	Meråker–Færen area (Wolff 1967, 1973, Chaloupsky & Fediuk 1967)	Steinkjer–Snåsa area (H. Carstens 1960, Peacey 1964, Roberts 1967b)	
Horg (Llandoverian)		*Upper Sandå Group* Hovin sandstone[1] Lyngestein conglomerate	*Slågån Group* Metasiltstone, phyllite		
Upper Hovin (Caradocian–Ashgillian)	Metagraywacke, conglomerates, volcanic sandstone; some pelite and acid tuffs	*Lower Sandå Group* Slates, some volcanic sandstone	*Kjølhaug Group* Metagraywacke, phyllite; conglomerate layers	Sandstone and shale, some conglomerate	
	Tautra limestone	Limestone and slate			
	Hopla conglomerate	Volla conglomerate		Polymict conglomerate	
Lower Hovin (Arenig–Caradocian)		*Krokstad Group*	*Sulåmo Group*		
	Dark shale or rhyolite tuff	Dicranograptus shale	Turifoss greenstone	(Steinkjer area)	(Snåsa area)
	Pelites, conglomerates and limestone (Åsen)	Hareklett rhyolite tuff Sandstone and shale	Sandstone and phyllite Local conglomerate	Pelite, sandstone and limestone	Greenstone and greenschist
	Stokkvola conglomerate	Local conglomerate	Brenna limestone		
	Forbordfjell greenstone	Jonsvatn greenstone and Hølonda andesite	Greenschist	Greenstone	Snåsa limestone
	Pelites, siltstone				
	Grønningen limestone	Hølonda limestone	Phyllite, sandstone	Phyllites	Local phyllite
	Phyllites	Slate, sandstone, breccia			
		Venna conglomerate	Lille Fundsjø conglomerate	Steinkjer conglomerate	
Støren (Cambrian–Tremadocian)[2]	Greenstone, greenschist	Greenstones	*Fundsjø Group* Greenstone, quartz keratophyre, some gabbros	Greenstones	
	[3]				
Gula (Cambro-Ordovician)[2]	Schists, some banded quartzite		*Sonvatn Group* Schists, gneisses, conglomerate and marble	Schists, amphibolite layers	

[1] Position of Hovin sandstone after Chaloupsky (1970). [2] Age range after Gale & Roberts (1974). [3] Tectonic boundary between Støren and Gula Groups.

which, in the present author's view, is probably an approximate time-equivalent of the Forbordfjell and Jonsvatn greenstone volcanism (Table 1).

Palaeontological evidence for the precise positioning of the Stokkvola conglomerate and Forbordfjell greenstone is comparatively meagre at the present time. The mapping results and the above correlations would indicate that these formations lie above the Whiterock (Llanvirnian) Hølonda limestone (Vogt 1945, Strand 1949, Neuman & Bruton 1974) which may well have correlatives in the prominent limestones of the Grønningen–Movatn area (Fig. 1).

Stratigraphically above the Stokkvola conglomerate is the Åsen limestone, halysitids from which denote an age not older than uppermost Caradoc (N. Spjeldnæs, written comm. 1974). The Stokkvola conglomerate may thus, provisionally, be placed within the time-range Llandeilo–Caradoc. It could be roughly equivalent to the pre-Caradocian disturbance noted by Størmer (1967) from the Mjøsa–Oslo Region, i.e. of approximate Llandeilian age. Further palaeontological studies, already planned, may help to resolve this question. It can be noted here that the author is currently investigating several of the limestones in the Åsen–Forbordfjell–Frosta district for microfossils, as yet without positive results.

The geology of the Frosta district north-west of Åsenfjorden is not without interest with regard to the dating and extent of the Forbordfjell volcanic episode. The Tautra limestone contains a variety of fossil material (H. Carstens 1960, Strand 1972) which appears to indicate an age of Middle Ordovician or younger, presumably at least Upper Caradoc (N. Spjeldnæs, written comm. 1974). The Tautra limestone extends onto the nearby Frosta peninsula where it is stratigraphically underlain by a polymict conglomerate containing abundant greenstone cobbles. Below this is a greenstone formation containing tuff horizons, as well as limestone, schist and thin quartzite intercalations. It seems probable from primary-structural and palaeontological evidence that the Frosta volcanics may correlate with the Forbordfjell greenstone, but in this particular area no distinction can be made between Hopla and Stokkvola-type conglomerates. The situation may therefore be more analogous to that observed at Skogn, perhaps with the volcanic episode here extending into the uppermost Lower Hovin. The Tautra limestone would then be slightly younger than the Åsen limestone, perhaps Ashgillian, and the highest parts of the Upper Hovin could be of Llandoverian age.

An important consequence of the re-positioning of the Stokkvola conglomerate pertains to references to the parorogenic Trondheim disturbance, a term which Holtedahl (1920) coined for the uplift represented by the greenstone conglomerate at the top of the Støren Group greenstone pile; the regional significance of this disturbance has also been discussed by the present writer (Roberts 1971). Holtedahl did not mention any specific name for the greenstone conglomerate, but Vogt (1928, 1945), unfortunately as it now transpires, used the name Stokkvola conglomerate in the manner of a type-lithology for this epeirogenic episode, and this has been accepted in Norwe-

gian geological literature over the years (e.g. Strand 1960, 1972, Oftedahl 1974).

As it now appears fairly clear that we cannot continue to use the name Stokkvola conglomerate as a synonym for, or as an indicator of, the Trondheim disturbance, it is suggested here that we could be on safer ground in adopting Vogt's (1945) designation *Venna conglomerate* from the classical Hølonda–Horg area when wishing to refer to a type-lithology characterising this uplift. The Venna, while of restricted occurrence, at least has local palaeontological evidence (Skevington & Sturt 1967) which places the Trondheim disturbance where Holtedahl (1920) had intended it. An alternative would be to retain Holtedahl's (1920) neutral term, but in a capitalized form, i.e. Greenstone conglomerate. This may be a preferable term in regional descriptions.

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