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Erosion and sediment yield in Norwegian rivers

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Abstract Sediment yield and processes of erosion in various parts of Norway are discussed in this paper. The specific sediment yield in the glacier area ranges between 100 and 1313 t km^{-2} $year^{-1}$. Bedrock geology seems to be important, but large valley glaciers are generally associated with higher sediment yields than small cirques and plateau glaciers. On Svalbard, a glacier sediment yield of 571 t km^{-2} $year^{-1}$ has been measured. Despite the soft rocks, this is much less than glaciers in comparable areas in Iceland and Alaska. This presumably reflects the limited movement of the sub-polar Arctic glaciers because parts of the glacier soles are frozen to the bedrock. Outside the glaciated areas, the magnitude of specific sediment yield is determined primarily by the character of the overburden. In forest areas, the main sediment sources are Pleistocene moraines and glaciofluvial deposits. Availability of sediment for erosion is limited and mean annual values of specific sediment yield are about 2 t km^{-2} $year^{-1}$. Occasionally, erosion is increased by gullying or mass movement and high yields have been recorded locally. In the mountain areas above the tree line, the processes of erosion are less affected by vegetation and yields are somewhat higher than in the forested lowlands. A specific sediment yield of 26 t km^{-2} $year^{-1}$ has been measured for the Foksåi basin in the Dovre mountains. Catchments outside the glacial areas in the high Arctic are an extreme member of this group. A specific sediment yield of 125 t km^{-2} $year^{-1}$ has been measured on Svalbard. In the areas below the limit of marine clay deposits, erosion rates are high. Specific sediment yields of up to 1256 t km^2 $year^{-1}$ have been measured in active ravine areas, whereas more stable ravines yield 158 t km^{-2} $year^{-1}$. In an exceptionally active area near Trondheim, a specific sediment yield of 3789 t km^{-2} $year^{-1}$ has been recorded.

INTRODUCTION

Systematic studies of sediment yields in Norway for various types of rivers were initiated by the University of Oslo in the late 1960s (Nordseth, 1974). Estimates of annual loads were based on sediment rating curves, using a similar approach to the Swedish national programme (Nilsson, 1971). A summary of the results obtained up to 1985 was provided by Bogen & Nordseth (1986). In 1968 an inventory of sediment transport in glacier meltwater streams was initiated by the Norwegian Water Resources and Energy Administration (Østrem, 1975). The programme at that time was based on manual methods, but at a frequency that is still maintained in present-day sediment sampling. The need for more extensive sediment data in river management in Norway was stressed by Bogen (1986). As result of this recommendation, NVE initiated a new programme that covered all types of rivers and also included investigations of the impact of human activity. The aim of this paper is to discuss results from this programme and to concentrate on data series that cover at least three years of observations. In recent years, institutions associated with the Agricultural University at Ås have conducted studies of soil loss on cultivated land. Some of these results are also included.

METHODS AND STRATEGY

One of the aims of the sampling programme is to analyse how the different processes of erosion leave their "signature" on the temporal variations in particle concentration. Thus, sampling frequency is mainly based on a time mode. ISCO automatic pumping samplers have been installed at all stations. For further description of the methods, see Bogen (1988; 1992). The locations of the monitoring stations discussed in this paper are shown in Fig. 1.

The river basins in Norway are of an extremely varying character and conditions differ greatly from one region to another and from high to low latitudes. The main difficulties when attempting to generalize with respect to processes of erosion and sediment yield are the large number of lakes, the dominating influence of bedrock geology and the thickness and nature of the overburden. Sediment sources are unevenly distributed across drainage basins, and only parts of the river courses are alluvial. A typical river basin may thus be composed of a number of local erosion and sedimentation sub-systems, and it may be difficult to evaluate the gross sediment yield from records collected at downstream stations only. One way to deal with such problems is to recognize the various types of sub-system and to derive sediment yields for monitoring stations covering " homogenous areas". These are areas where soils and processes of erosion and sediment production are essentially of the same type. It was found that the most meaningful results were obtained when a "contributing area" was defined. This area is the part of the catchment situated downstream from major lakes. Five types of river were recognized, namely, rivers draining marine clay areas, rivers draining the forested upland, rivers in the arctic and mountain areas, glacier outlets, and glacier fed rivers (see Fig. 2 and Table 1). In addition, sediment yields from cultivated land are discussed. There is a high variability within each group, but they provide a valuable basis for further analysis of the processes of erosion.

MARINE CLAY AREAS

Extensive areas in southeast and central Norway were submerged during the end of the last Ice Age. The silt and clay deposits found in these areas are susceptible to erosion and are in parts subject to intense gullying. The remaining areas are cultivated land. An examination of the stability of the gullies revealed the presence of two types. In the Slemdalsbekken type, the dominant processes were landslides released by the instability initiated by the lowering of the main stream that takes place during major floods. In the stable type, small flood plains were often found alongside the main channels, and lateral

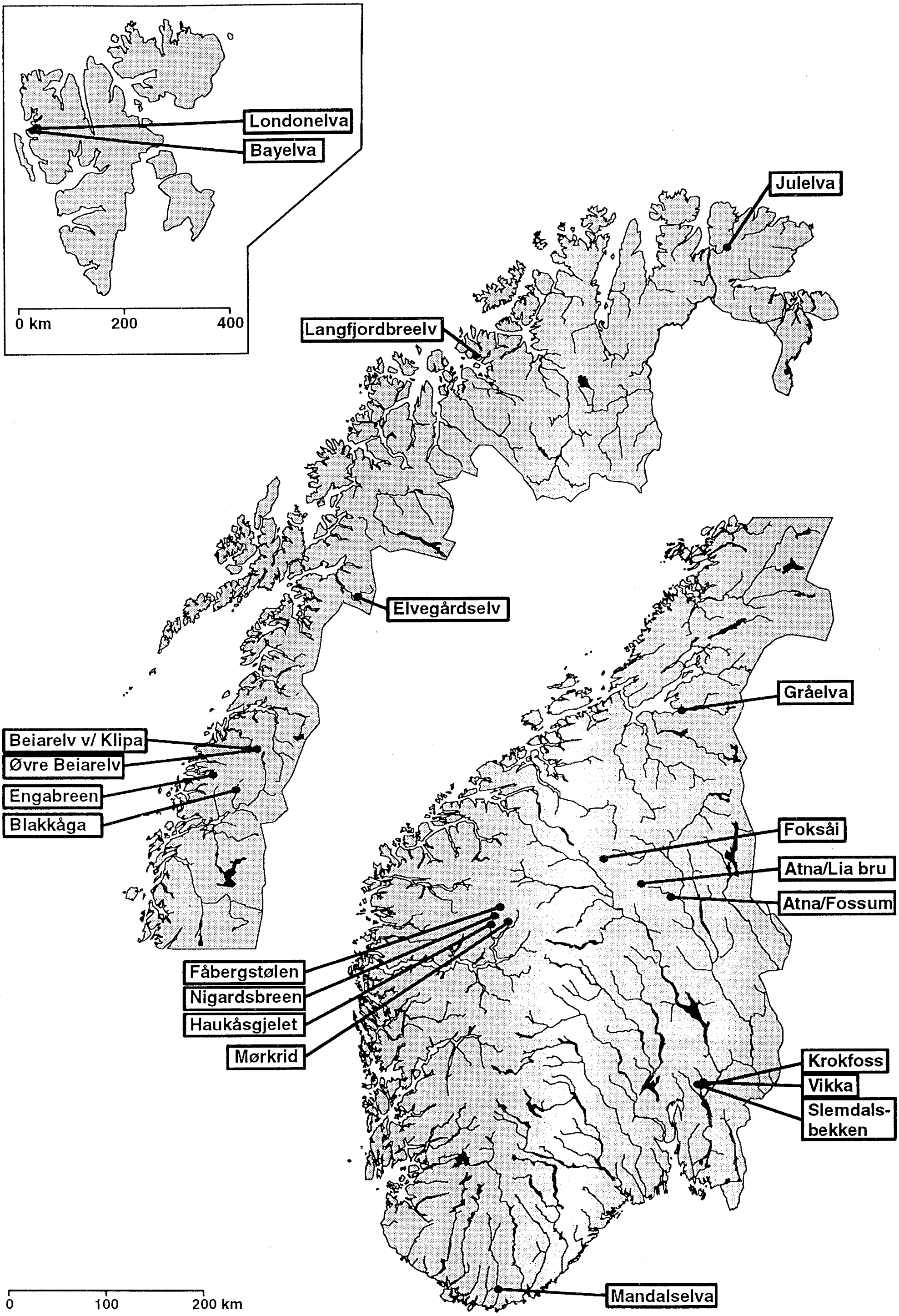

Fig. 1 Sediment yields from various types of river basin in Norway.

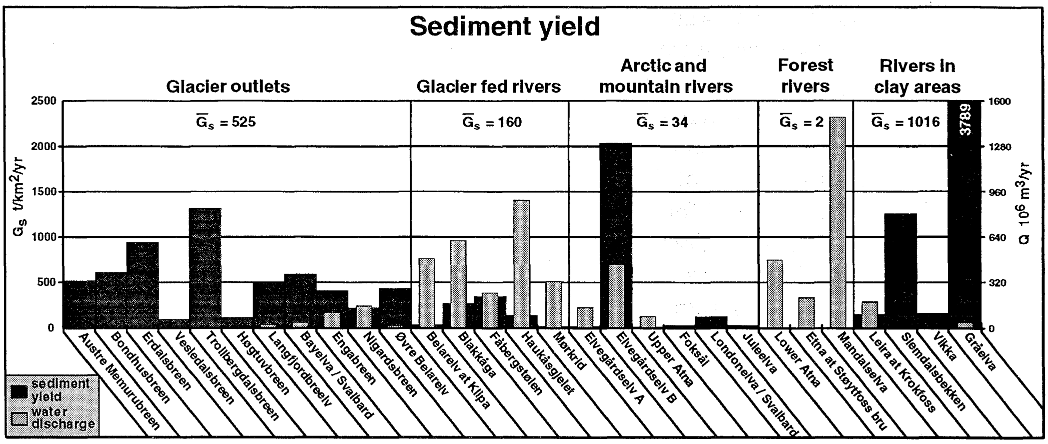

Fig. 2 Sediment yields (t km^{-2} year^{-1}) and total annual discharges ($\times$ 10^6 m^3 year^{-1}) for various types of Norwegian rivers. *Gs* is the mean sediment yield of each group. An exception is the group "Arctic and mountain rivers" where the year of a major flood 1993 (Gamvik B) was not included in the mean.

Table 1 Sediment yields and transport rates for rivers included in this paper.

	Station	A km^2	CA km^2	Years of observation	G_s Mean t/yr	g_s t/km^2/yr	Mean Q=10^6 m^3/yr
Glacier outlets	Austre Memurubreen	9.0	9.0	6	4730	526	
	Bondhusbreen	11.0	11.0	2	6760	615	
	Erdalsbreen	11.0	11.0	6	10410	946	
	Vesledalsbreen	4.0	4.0	6	395	99	
	Trollbergdalsbreen	2.0	2.0	5	2625	1313	
	Høgtuvbreen	2.6	2.6	3	304	117	
	Langfjordbreelva	4.6	4.6	5	2199	475	20.70
	Bayelva / Svalbard	17.1	17.1	6	9767	571	31.43
	Engabreen	36.2	36.2	7	15550	430	108.95
	Nigardsbreen	48.2	48.2	8	9718	202	156.58
	Øvre Beiarelv	2.4	2.4	6	1172	482	16.00
Glacier fed rivers	Beirelv at Klipa	350.0	350.0	6	12200	35	488.61
	Blakkåga	303.0	303.0	5	81878	270	618.01
	Fåbergstølen	185.0	185.0	9	63763	345	247.77
	Haukåsgjelet	573.0	573.0	9	74870	131	900.14
	Mørkrid	203.0	203.0	7	3940	19	325.38
Arctic and mountain rivers	Elvegårdselv A	797.0	119.4	2	2122	18	145.03
	Elvegårdselv B	797.0	119.4	1	242958	2035	444.50
	Atna at Lia bru	132.0	30.0	8	361	12	78.84
	Foksåi	27.9	10.0	3	261	26	12.81
	Londonelva / Svalbard	0.7	0.7	3	88	125	0.69
	Juleelva	6.7	1.1	3	26	23	5.74
Forest rivers	Atna at Fossum bru	1138.0	673.0	8	1938	2.88	481.56
	Etna / Støytfoss bru	557.0	300.0	6	679	2.26	214.90
	Mandalselva	1740.0	1740.0	2	813	0.47	1479.98
Rivers in clay areas	Leira at Krokfoss	418.0	180.0	6	27320	152	181.67
	Slemdalsbekken	4.8	4.8	4	6028	1256	2.46
	Vikka	5.0	3.6	6	570	158	1.80
	Gråelva	47.6	20.0	5	75787	3789	36.40

erosion and soil creep were the dominant processes. The mean annual specific sediment yields of the two types were 1256 and 158 t km^{-2} year^{-1} respectively. The mean sediment yield of agricultural land within these two catchments was estimated to be 380 and 177 t km^{-2} year^{-1} (Bogen *et al.*, 1994). The mean sediment yield of the clay area upstream of Krokfoss on the River Leira is 152 t km^{-2} year^{-1} (Table 1).

The sediment yield of the River Gråelva amounts to 3789 t km^{-2} year^{-1}. This is the highest value on record for rivers that have been subject to monitoring in the long-term programme. The river drains an unstable clay area where the main channel is subject to degradation. Channel erosion seems to represent a major contribution to the sediment budget. Sediment transport is subject to a high year to year variability, even if the total runoff does not change during the period of observations (Fig. 3).

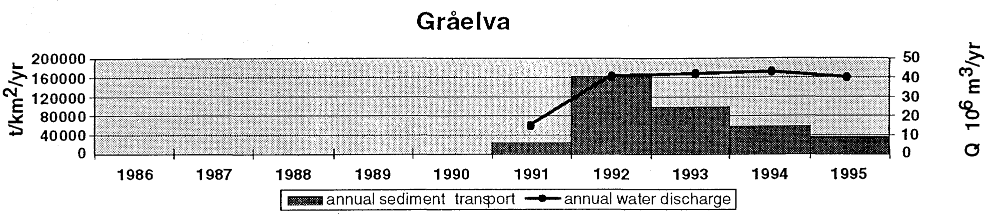

Fig. 3 Annual sediment transport and water discharge in the River Gråelva, near Trondheim.

EROSION ON CULTIVATED LAND

Erosion on cultivated land has been studied by institutions associated with the Agricultural University at Ås. A long-term study of soil erosion in small catchments in southeastern Norway was initiated in 1984. The soil type in the catchment "Holt 1" is composed of silty clay and its slopes were levelled in 1974. The mean sediment yield in this catchment was recorded at 356.7 t km^{-2} year^{-1} and may be compared with the value of 85.0 t km^{-2} year^{-1} for the tills of "Enerstujordet", (Lundekvam, 1993). Surface erosion accounted for 54% of the total load in Holt 1, whereas erosion in furrows and soil loss in drainage accounted for 33% and 13% respectively. Soil management practices and the timing of soil tillage in particular are important factors controlling the annual rates of erosion. However, weather and runoff conditions are also critical. Measurements in five small catchments in the Romerike area demonstrate this effect (Øygarden, 1994). 1989 was a dry year and a very low yield was observed. A winter flood event involving intense runoff on partly frozen ground caused the high yield in

Table 2 Sediment yields of small catchments on cultivated land (from Øygarden, 1994).

catchment no.	1987 t/km²	1988 t/km²	1989 t/km²	1990 t/km²	1991 t/km²	1992 t/km²	Mean t/km²
101	74	26	7	152	8	108	63
102	52	15	3	157	10	20	43
106	202	186	72	263	57	20	133
107	301	276	142	31	34	12	133
108	112	40	20	494	84	358	185

1990 (Table 2). The unusual conditions during the winter of 1990 influenced large areas in eastern Norway. In the River Leira the sediment load recorded in January and February amounted to about 65% of the total load for that year. Under these conditions it is believed that a major part of the sediment originated from agricultural areas. However, sediment budget studies carried out by Bogen *et al.* (1994) indicated that 45% of the long term mean was supplied from erosion of cultivated land and 55% originated from gully and river erosion in this river basin.

FORESTED AREAS

About 25% of the total area of Norway is covered by forests. The main sediment sources within this region are moraines and glaciofluvial sediments deposited by Pleistocene glaciers. In general, these deposits are thicker and more extensive than at higher altitudes in the high mountain region. The lower parts of the Rivers Atna and Etna have been selected as typical of this region. Both are situated in the extensive coniferous forests of eastern Norway. When the measured loads are related to the area downstream of the major lakes, their specific yields are 2.88 t km^{-2} $year^{-1}$ (mean of 8 years) and 2.26 t km^{-2} $year^{-1}$ (mean of 7 years), respectively. The patchy distribution of sediment sources is probably the main reason for the poor correlation with water discharge (Fig. 4).

The forest vegetation provides an efficient protection against erosion. However, when the vegetation is weakened, for example due to clear felling, suspended sediment production may increase considerably, and in some areas debris slides or gully incision can occur. However, due to the more favourable climate, the regrowth of vegetation takes place at a faster rate than in the high mountain region. The sediment yields of single gullies on moraines inside the forested upland region have been shown to be as high as 8000 t km^{-2} $year^{-1}$ (Hagen, 1986). Thus, a higher sediment yield is to be expected if gullies or large erosion scars develop in the river basins. Major floods give rise to long-term variability in sediment yield. During such floods erosion scars may be

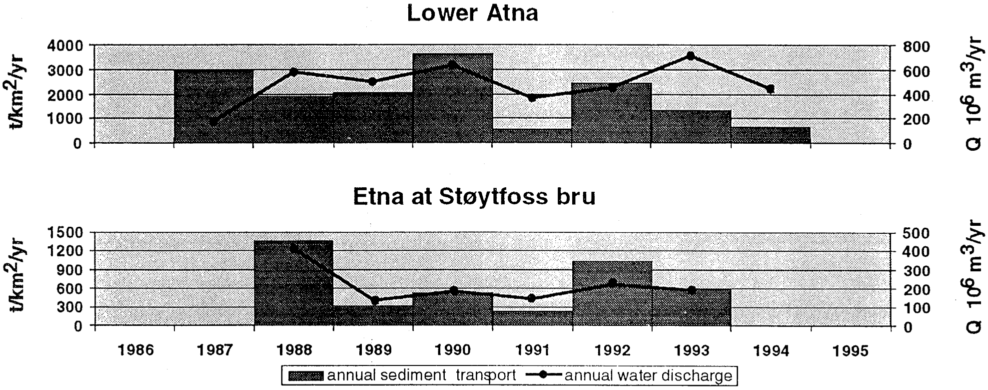

Fig. 4 Annual sediment transport and water discharge in the lower Atna at Fossum Bridge and in the River Etna at Støytfoss bridge.

opened in a number of new locations in such a way that the sediment inputs to downstream reaches are greatly increased.

In the southernmost part of Norway, the overburden is very thin and patchy. Sediment yields as low as 0.47 t km^{-2} $year^{-1}$ have been measured for Mandalselv in this area. For the steep rivers along the fjords or fjord valleys in the western and northern part of the country, data are scarce, but one-year records indicate somewhat larger values. The Videdøla river yielded 18.4 t km^{-2} in 1987 (Bogen, 1989) and 16 t km^{-2} $year^{-1}$ was recorded in the catchment of Bukkebekken, a stream flowing next to Engabreen. These rivers are, however, in a transition zone to the high mountain region. In many areas, there is no distinct border between the two regions.

ARCTIC AND MOUNTAIN AREA

High relief and steep slopes are characteristic features of the mountain areas. However, steep slopes also occur in the lowlands. Large parts of the high mountain areas in Scandinavia are also subdued, with an extensive plateau at 1200-1500 m a.s.l. Thus, the most important factor that makes the mountain areas different from lowlands with respect to processes of erosion is the cold climate and the limited vegetation. The presence of vegetation prevents erosion by surface runoff through its direct protection and indirectly by increasing infiltration capacity. Vegetation also increases the evapotranspiration and thus reduces the total runoff. The tree line is a distinct feature that provides a boundary between the forests and the arctic and mountain area. In southeastern Norway the tree line is at an altitude of 900 m, falling to 300 m a.s.l. in northern Norway. The mountain area, defined as the area above the tree line, comprises more than 50% of the total land.

The sediment yields of the mountain rivers are somewhat larger than those of the forest area. The upper part of the River Atna drains the western part of the Rondane mountains. About 30 km^2 of this area is covered by extensive deposits of Pleistocene sediments. Outside this area, the sediment yield is negligible. A sediment yield of 12 t km^{-2} $year^{-1}$ (mean of 8 years) was recorded in the main contributing area. The conditions in the nearby Foksåi catchment are essentially of the same kind, but a higher yield of 26 t km^{-2} $year^{-1}$ was recorded. Floods caused by snowmelt or extreme rainfall may destroy the protective vegetation and have a severe impact on erosion rates. In the River Elvegårdselv at Gamvik in northern Norway, sediment monitoring during a flood event in 1993 gives some indication as to the erosion rates to be expected. During the years of normal runoff, 1992 and 1994, a mean sediment yield of 17.8 t km^{-2} $year^{-1}$ was found. Due to a large flood in 1992, the sediment yield for that year increased to 2034 t km^{-2} $year^{-1}$ (see Table 1). A large debris flow event was triggered by the rainfall and some of the high yield was derived from this incident. However, extensive river diversions have been carried out in the drainage basin. The measured yield is related to the remaining catchment area. As overflow may have occurred during the flood peak, the yield originating from the debris flows is likely to be somewhat lower. The following year, the sediment yield was again at a moderate level. Rapp & Strømqust (1976) and Rapp *et al.* (1991) have described debris flow events resulting from heavy rain in the Scandinavian mountains. They point to the fact that as regrowth of vegetation is slow in a cold climate, accelerated erosion caused by extreme rainfall may have long lasting effects.

The River Julelva in northern Norway is situated in the mountain areas of the Varangerhalvøya peninsula. This river was included to obtain data relating to the contribution from recent weathering processes to the sediment transport. From visual observations, conditions seemed to be optimal for the frost shattering of rocks in this area. The measurements gave a sediment yield of 23 t km^{-2} year^{-1}. The bedrock consists of low-metamorphic siltstones and sandstones that are susceptible to physical weathering. In the mountain areas in mainland Norway, the bedrock is more resistant and the rate of weathering is believed to be much lower.

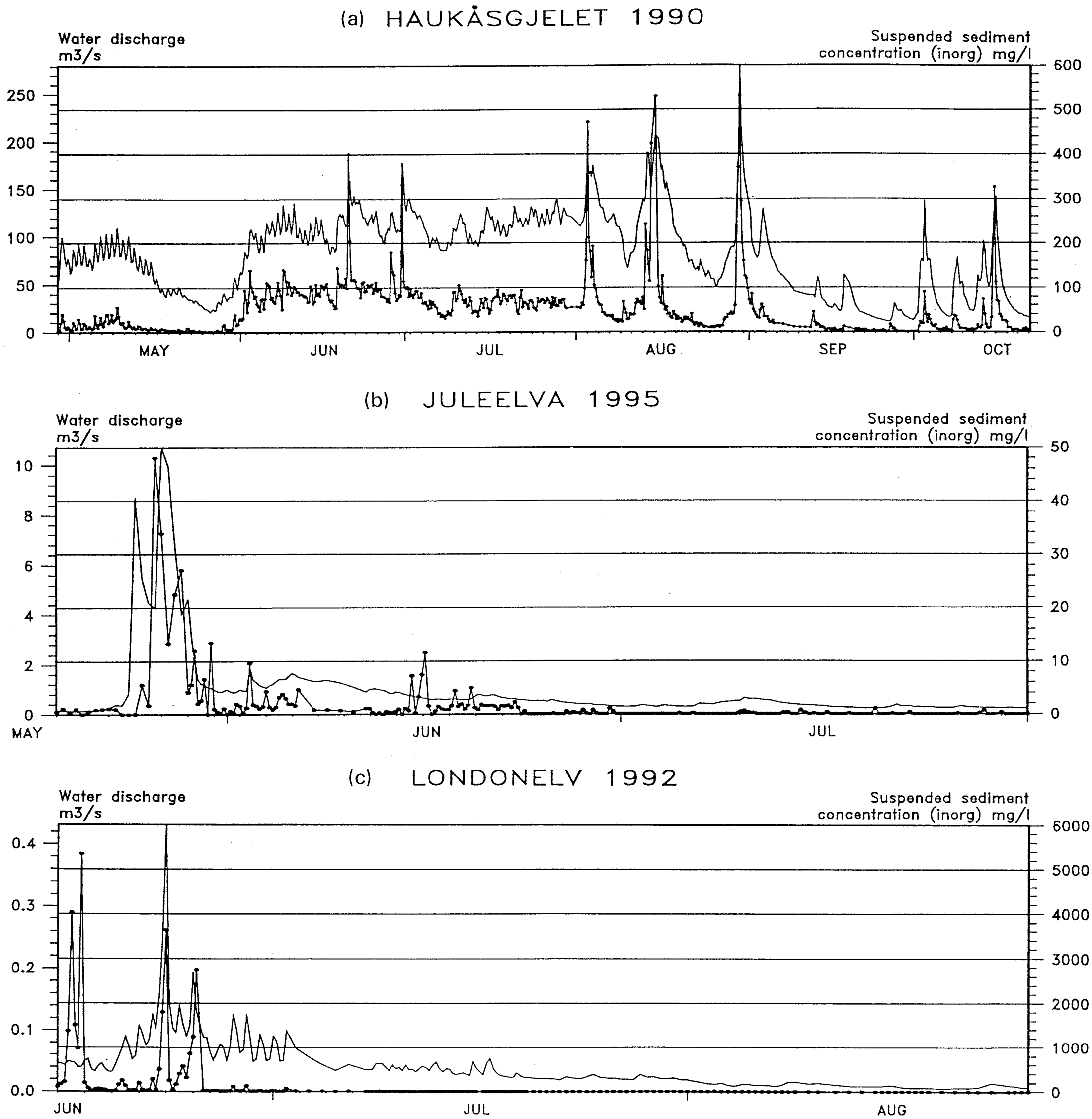

Fig. 5 Water discharge and sediment concentration in: (a) the Jostedøla at Haukåsgjelet; (b) the Julelva at Varangerhalvøya; and (c) the Londonelv near Ny Ålesund, Svalbard.

The River Londonelv, on Svalbard, was included to obtain data on erosion rates outside the glacier areas in the high Arctic. Workers in high Arctic regions have often emphasized what is unique rather than what is common with lower latitudes. Fluvial activity is a distinct feature of the arctic environment on Svalbard, but processes of erosion outside the glacier areas have not been subject to much investigation. The sediment regime is to a some extent similar to that of the Julelva. The two streams are compared with the more complicated regime of the glacier fed River Jostedøla in Fig. 5. In the Julelva and Londonelv most of the runoff and sediment transport takes place during a short melting period in late June. At Londonelv, permafrost is universal. During the short summer, the ground thaws to a maximum depth of 2 m. Land surfaces are only patchily covered by till or frost-riven bedrock material. A major part of the catchment consists of bedrock exposures of carbonate rocks. A relatively high sediment yield of 125 t km^{-2} $year^{-1}$ was found as a mean of three years. Most of the sediment passing the monitoring station seemed to be eroded from a 500 m long and 200 m wide upstream flood plain deposit. Thus the primary source of sediment is channel erosion of the flood plain, but the long term availability of sediment for transport seems to be dependent on the supply from physical weathering processes.

THE GLACIER FED RIVERS

The sediment loads of these rivers include both sediments from glacial erosion and sediments from erosion of moraines and glaciofluvial deposits in the high mountain areas. The monitoring stations are situated downstream in the river basins and the load is transported from several glaciers and the surrounding areas. The mean sediment yield based on the whole basin area is not satisfactory, but gives an indication of the erosional activity in these river basins. The highest yield in the basin at Fåbergstølen is in part due to erosion of a sandur. A channel change took place in 1991 and caused very high loads during certain years (Bogen, 1995). This incident is also apparent at Haukåsgjelet, a downstream station on the same river basin (Fig. 6). The low yield of the River

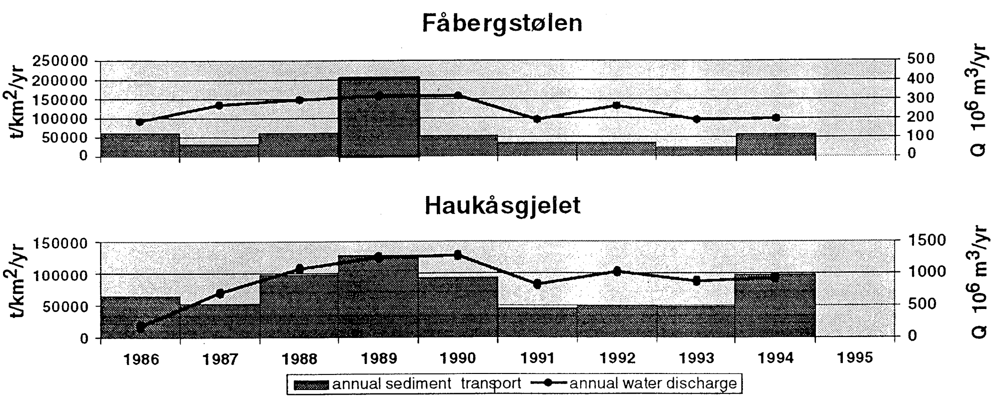

Fig. 6 Annual sediment transport and water discharge at Fåbergstølen and Haukåsgjelet on the River Jostedøla. Haukåsgjelet is situated downstream from Fåbergstølen on the same river.

Mørkridselv probably reflects the low erosion rates associated with the thin plateau glaciers in the area. Blakkåga is a river draining the southeastern part of the Svartisen ice cap in northern Norway. The glaciers in this river basin have not been investigated in detail but the high loads suggest that their erosion rates are among the highest on the Norwegian mainland.

THE GLACIER OUTLETS

The glacier covered areas are in fact part of the arctic and high mountain region. However, as the processes and rates of erosion deviate considerably from the sub-aerial case, it is recognized as a different region. Sediment transport monitoring programmes on glacier meltwater rivers have in many cases been carried out at stations situated at the glacier fronts. These investigations have shown that the variations between different types of glacier are large, and sediment yields range between 100 and 1300 t km^{-2} $year^{-1}$ (Østrem, 1975; Bogen, 1989). The greatest intensity of erosion occurs beneath large valley glaciers with several tributaries. The yield of small cirques or plateau glaciers is an order of magnitude lower. An exception is the small Trollbergdalsbre cirque glacier which is resting on schistose rocks and possibly also on a soft bed. In mainland Norway, almost all of the sediment in the meltwater is derived from sub-glacial processes of erosion. The sediment yield of the hillslopes that drain down to the glacier surface is in the range 10 to less than 1 t km^{-2} $year^{-1}$.

Sub-glacial erosion is carried out by scour and abrasion that convey a continuous supply of debris to the glacier sole. These processes should not be expected to be subject to year to year variations and are most probably related to long-term means of sediment transport. Bogen (1996) suggested that the pattern of year to year variability in sediment yield is related to the melt out of sediment from the ice. When a glacier deforms its drainage system by its movement or plastic deformation, debris is introduced into the sub-glacial waterways by melting of sediment-laden ice surrounding the conduits or linked cavity systems at the glacier bed. Due to variations in glacier melting and precipitation, such changes take place several times throughout the season. This mechanism may account for observed differences in the pattern of year to year variability between glaciers (Fig. 7).

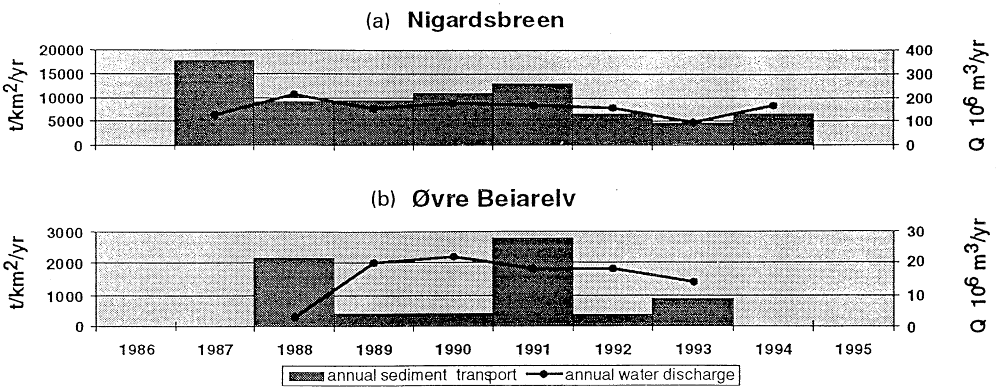

Fig. 7 Runoff and sediment yield from glacier outlets: (a) the large and active valley glacier of Nigardsbreen; and (b) the small and receding glacier Øvre Beiarbre.

The sediment yields of Norwegian glaciers are small when compared to glaciers elsewhere. Sediment yields of up to 6000 t km^{-2} $year^{-1}$ have been reported for glaciers in the Alps, while a value of 12 000 t km^{-2} $year^{-1}$ has been recorded for the Vatnajøkull on Iceland and values of 22 000 t km^{-2} $year^{-1}$ have been documented in Alaska (see Bogen, 1989; Hallet *et al.*, 1996). The very hard igneous and metamorphic rocks in the glacier areas are the main reason for this fact. On Svalbard, where the bedrock is low grade metamorphics and more susceptible to erosion, the glaciers are sub-polar. That is, parts of the glacier bed are frozen to the bed and thus limit erosion.

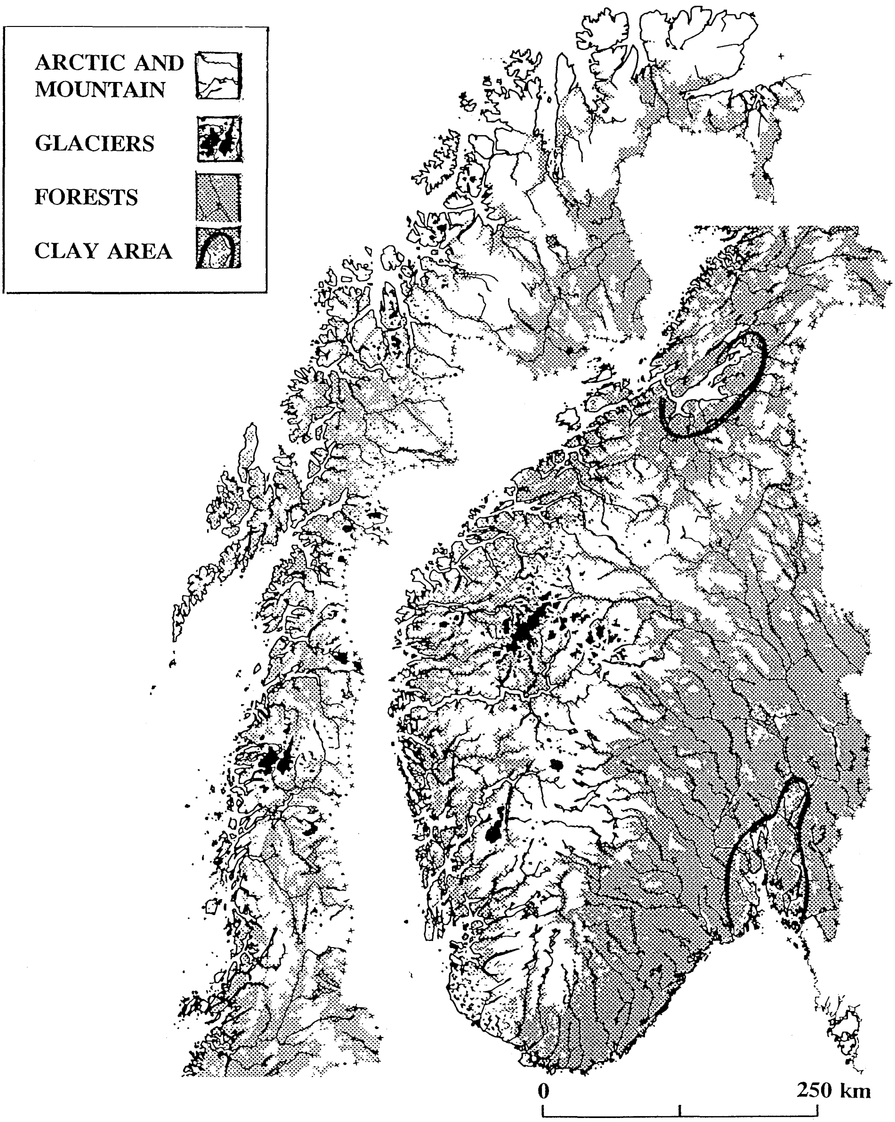

Fig. 8 The areal extent of forest, arctic and mountain, glacier, and marine clay areas on the Norwegian mainland.

DISCUSSION

The results from the recent survey of sediment yields in Norwegian rivers deviate to some extent from earlier reports given by Nordseth (1974) and Bogen & Nordseth (1986). A general map of the regions is shown in Fig. 8. The main types of rivers are retained, but new data allow for the recognition and characterization of rivers in the arctic and mountain regions. Recent work has also provided more data on erosion on cultivated land. The most remarkable difference from the early reports is the high sediment yields that have been observed in some clay areas. These values have been found to be related to the landscape development. The recent data from rivers in the forested region suggest lower yield than previously measured. Rainfall flood events do however periodically cause excessively high sediment yields, both in the forests and in the mountain region. Many rivers are of a composite type, since they receive sediment from tributaries of various types. Their sediment budgets may however be assessed on the basis of the main types given in Fig. 2.

REFERENCES

Bogen, J. (1986) Erosjonsprosesser og sedimenttransport i norske vassdrag. Utredning av forvaltningsansvar, faglig status og forskningsbehov (Erosion and sediment transport in Norwegian rivers. River management, responsibilities, status and research requirements). *NHK Report no. 20.*

Bogen, J. (1988) A monitoring programme of sediment transport in Norwegian rivers. In: *Sediment Budgets* (ed. by M. P. Bordas & D. E. Walling) (Proc. Porto Alegre Symp., December 1988), 149-159. IAHS Publ. no. 174.

Bogen, J. (1989) Glacial sediment production and development of hydroelectric power in glacierized areas. *Ann. Glaciol.* **13**, 6-11.

Bogen, J. (1992) Monitoring grain size of suspended sediments in rivers. In: *Erosion and Sediment Transport Programmes in River Basins* (ed. by J. Bogen, D. E. Walling & T. Day) (Proc. Oslo Symp., August 1992), 183-190. IAHS Publ. no. 210.

Bogen, J. & Nordseth, K. (1986) The sediment yield of Norwegian rivers. In: *Partikulært Bundet Stofftransport i vann og Jorderosjon* (ed. by B. Hasholt), 233-252. NHP Report no. 14, KOHYNO (Coordination Committee of Hydrology in the Nordic Countries).

Bogen, J., Sandersen, F. & Berg, H. (1994) The contribution of gully erosion to the sediment budget of the river Leira. In: *Variability in Stream Erosion and Sediment Transport* (ed. by L. J. Olive, R. J. Loughran & J. A. Kesby) (Proc. Canberra Symp., December 1994), 307-315. IAHS Publ. no. 224.

Bogen, J. (1996) Erosion rates and sediment yield of glaciers. *Ann. Glaciol., Proc. Reykjavik Symp.* (in press).

Hagen, K. (1986) Sedimentproduksjon i et ravinefelt i morene (Sediment production in a gully developed in till) The valley of Uladalen in Gudbrandsdal (in Norwegian). Unpublished thesis, Dept of Geography, Univ. of Oslo.

Hallet, B., Hunter, L. & Bogen, J. (1996) Rates of erosion and sediment evacuation by glaciers: A review of field data and their implications. *Global and Planetary Change* (in press).

Lundekvam, H. (1993) Jordovervakingsprogrammet(The soil monitoring programme). Report 7/1993, Avrenningsfelta ved Institutt for Jord og Vassfag (Dept of Soil and Water Sciences).

Rapp, A. & Strømquist, L. (1976) Slope erosion due to extreme rainfall in the Scandinavian mountains. *Geogr. Ann.* **58A**(3), 193-200.

Rapp, A. (1991) Mudflow disasters in mountainous areas. *Ambio* **20**(6), 210-218.

Nilsson, B. (1971) Sedimenttransport i svenska vattendrag (Sediment transport in Svedish rivers). *Et IHD Prosjekt. Del 1. Metodik., Natgeogr. Inst. Univ. i Uppsala, Report no. 4.*

Nordseth, K. (1974) Sedimenttransport i norske vassdrag (Sediment transport in Norwegian rivers) Univ. of Oslo, Dept of Geogr. Int. Report.

Østrem, G. (1975) Sediment transport in glacial meltwater streams. In: *Glaciofluvial and Glaciolacustrine Sedimentation* (ed. by A. V. Jopling & B. C. McDonald), 101-122. Soc. Econ. Pal. Min. Spec. Publ. no. 23.

Øygarden, L. (1994) Soil tillage and erosion in small catchments. In: *Proc. 13th ISTRO Conference: Soil Tillage for Crop Production and Protection of the Environment* (Aalborg, Denmark, July 1994), 263-269.