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Control of glacial and fluvial environments in the Ny-Alesund region, Arctic

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सार – स्वॉलबर्ड, आर्कटिक में स्थित नि–एलसंड में जलवायु और विवर्तनिकी के सीधे नियत्रंण में आने वाले विभिन्न तलछटी पर्यावरणों द्वारा विकसित मिश्रित स्थलाकत्रति और भू आकृति के अभिलक्षणों का पता चला है। हिमनद और नदीय पर्यावरणों के नियंत्रणों को को छोटी घाटी के हिम नदियों (वेस्ट्रे ब्रोगर और मीड्रे लोवन) और इनसे उत्पन्न हुए प्रवाहों द्वारा विकसित भू आकृतिक अभिलक्षणों के फील्ड डॉक्यूमेंटशन के आधार पर विश्लेषण किया गया है। इन स्थलीय घाटी के हिमनदों को उत्तल वलीय सतह, हिम–विदरों, वर्गश्रंडों, अधिहिमानी धाराओं, अनुदैध्र्य ड्रेबरीस स्ट्रिप्स, पार्श्विक मोरेन, प्रतिसारी मोरेन, कुकुदी मोरेन, क्षेप मोरेन, स्लोप विचलन सहित उत्तल अनुदैर्ध्य प्रोफाइल, फैक्चर और ज्वाइंटस द्वारा अभिलक्षित किया गया है। हिमनद डिपाजिस्ट को क्लास्ट मैटिक्सक और ग्रैवेल के अलग– अलग प्रकार के आकारों में मैट्रिक्स समर्पित बाउलडरो में अपर्याप्त रूप से निकाले गए क्लास्ट से बनाया जाता है। क्लास्ट समर्पित फैशीस से निचले भाग में मैट्रिक्स समर्पित फैशीस द्वारा ग्लेशियर की ऊर्जा में वृद्धि के कारण शीत जलवायु का पता चला है। मौरनों के बायोमॉडल पुराधारा पैटर्न से विवर्तनिकी गतिविध के सीधे नियंत्रण के तहत पूर्व में ग्लेशियरों के खिसकने के दो प्रमुख दिशाओं को पता चला है। प्रवाहों के ग्रेनउलोमैट्रिक विश्लेषण से अपरिष्कृत रेत से सामान्य रूप से खुरदरे से मध्य में निकाले गए रेत का पता चला है। माध्य ग्रेन का आकार समुद्र के मूल भाग से मध्य भाग की ओर कम होता जाता है और इसके सिरे की ओर बढ़ता जाता है। डाउनस्ट्रीम दिशा में अच्छी तलछटों का प्रतिशत कम होता है और खुरदरे खंडों/ टुकड़ों का प्रतिशत बढ़ता है। ग्राउन मैट्रिक प्राचलों के परिणाम विवर्तनिकी गतिविधि के नियंत्रण के कारण सामान्य नदीय प्रणाली के विपरीत होते है।

यह अध्ययन हिमनद और नदीय पर्यावरण की गतिविधियों और मौलिक लक्षण उपलब्ध कराता है जो इस क्षेत्र में विवर्तनिकी गतिविधि के नियंत्रण को बताता है।

ABSTRACT. Ny-Alesund, located in Svalbard, Arctic exhibits complex topography and geomorphic features evolved by various sedimentary environments under direct control of climate and tectonics. The controls of glacial and fluvial environments were analyzed on the basis of field documentation of geomorphic features evolved by small valley glaciers (Vestre brogger and Midre loven) and streams originating from it. These terrestrial valley glaciers are characterized by convex wrinkled surface, crevasses, bergchrunds, supraglacial streams, longitudinal debris strips, lateral moraines, recessional moraines, hummocky moraines, thrust moraines, convex longitudinal profile with breaks in slope, fractures and joints. The glacial deposits are made up of very poorly sorted clast to matrix supported boulders with varying sizes of clast, matrix and gravels. The matrix supported facies underlain by clast supported facies indicate the increasing energy of the glacier and so the cold climate. The bi-modal palaeocurrent pattern of moraines suggests two prominent directions for the movement of glaciers in the past under direct control of tectonic activity. The granulometric analysis of the streams indicate moderately sorted medium to coarse sand. The mean grain size decreases from origin to the middle reaches of the river and increases towards its mouth. The percentage of the finer sediments decreases and coarser fragments increases in the downstream direction. The results of the granulometric parameters which are contrary to the normal fluvial system are due to the control of tectonic activity.

The present study provides the basic characteristics and activity of the glacial and fluvial environments the interpretation of, which explains the control of tectonic activity in this region.

Key words – Arctic, Glacial, Fluvial, Landforms, Climate, Tectonics.

1. Introduction

Ny-Alesund, Svalbard, Arctic provides varied geological structures and geo-historical development since the palaeo-Proterozoic time. It has experienced significant environmental, climate and landscape changes during the last few centuries (Overpeck *et al.*, 1997). This region is carved mainly by glacial activity, however, other surface

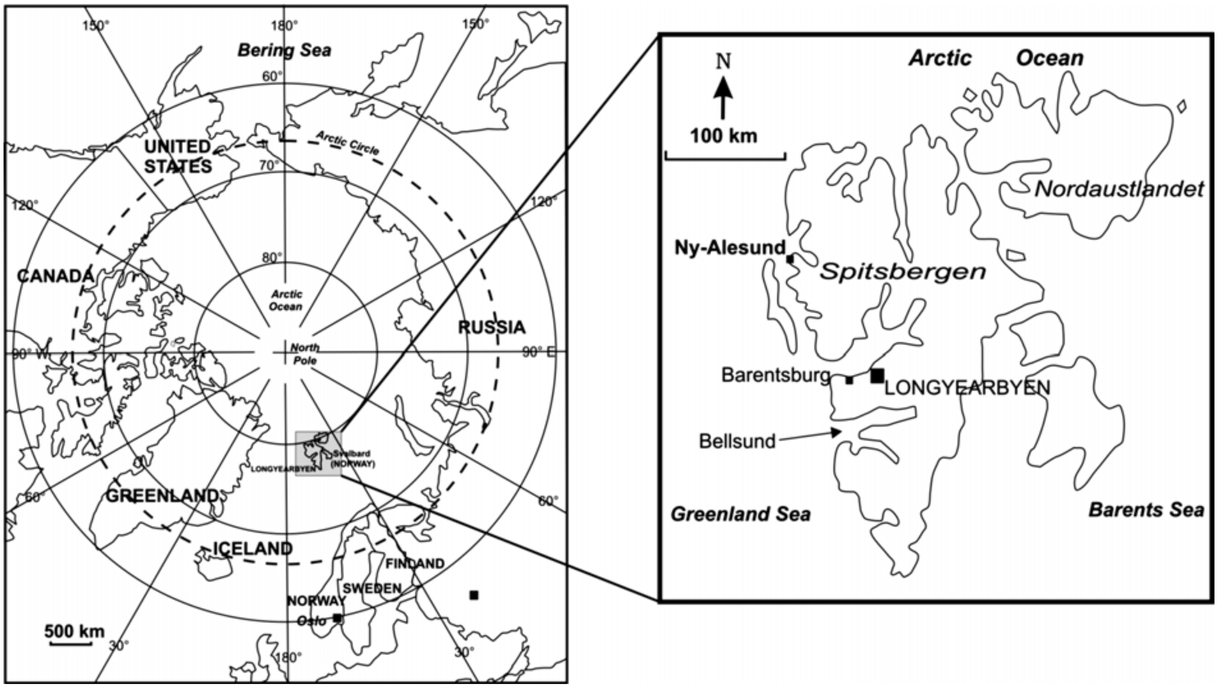

Fig. 1. Showing location of Spitsbergen and Ny-Alesund

and subsurface processes also contribute in shaping the landforms/landscape of this region.

The fluctuation of glaciers and discharge of its melt water stream are considered as one of the best indicators of climate change as they decreases and increases in direct response to the climatic turnover. The analysis and documentation of geomorphic features and their associated depositional environment are important in understanding the landforms and landscape evolution and their relationship with the climate and tectonics. However, the characteristics of these sedimentary environments in the Ny-Alesund region mainly the glacial and fluvial data base is quite limited with paucity of observations, making it difficult to analyze and interpret its control for the landscape evolution.

The present paper describes the characteristics of the glacial and fluvial environments with special reference to the geomorphic features which explain the control of these sedimentary environments.

2. Glacial and fluvial environments and landforms

Sedimentary environment has mainly four important components, place, process, medium and material of deposition and refers simply to the place or medium of deposition and to the physical, chemical and biological conditions which characterizes the depositional setting and evolve the landscape. The major criteria currently used in recognizing the characteristics of the depositional environments are the nature of sediments such as bedding plane, contact between the beds, small to large scale structures, directional properties, gross composition of the rock and total faunal and floral assemblage which can be identified and measured in the field. Every sedimentary environment is characterized by its own energy level and so the capacity for transportation and deposition of sediments of particular grain size with diagnostic sedimentary structures under direct control of climate and tectonics. Thus, sedimentary environment is characterized by its typical sedimentary parameters. The area is characterized by the dominance of glacial landforms, however, the glacio-fluvial and fluvial geomorphic features are also present and can be identified on the basis of above criteria.

Svalbard is an archipelago in the Arctic Ocean, located about midway between Norway and the North Pole. Spitsbergen is the main island of Svalbard archipelago and Ny-Alesund is located on the western coast of Spitsbergen (Hjelle, 1993; Elvevold, 2007) (Fig. 1).

The glacial environment present as snow, glaciers, ice sheets, sea ice and permafrost is the prominent feature of this region. The majority of the glaciers belongs to the sub polar type (Liestol, 1988) and may be classified as ice

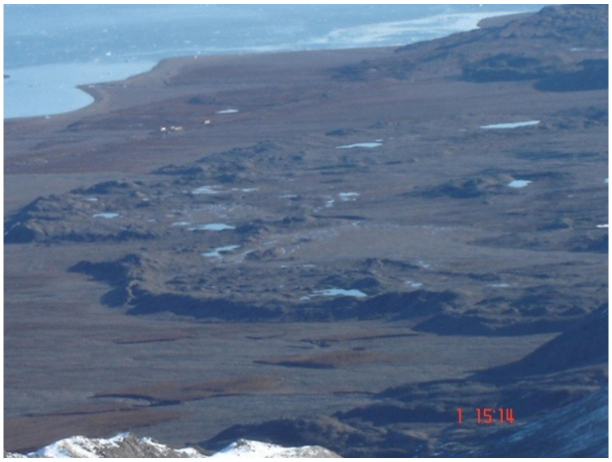

Fig. 2. Showing lateral, recessional, hummocky moraines, kettles, outwash plain and the ocean

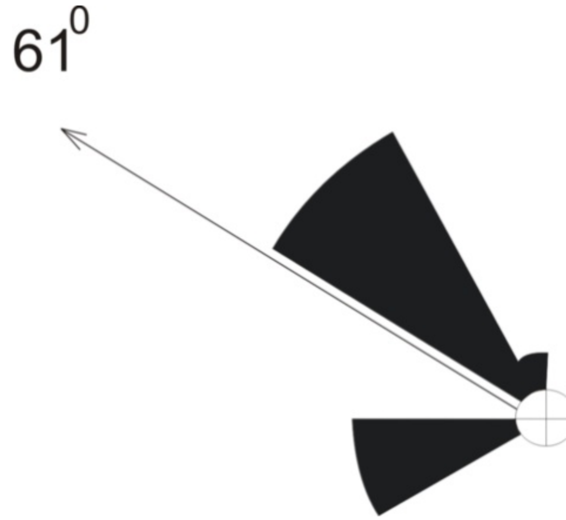

Fig. 3. Showing Bimodal palaeocurrent patterns

cap, valley glaciers, cirque glaciers, tidal glaciers, rock glaciers, and talus cone glaciers (Singh and Ravindra, 2011). Small valley glaciers ending on land usually have very low velocities. It erodes and deposits the debris to form a number of geomorphic features characterized by poorly sorted angular coarse grain sediments, which are devoid of any sedimentary structures. Very low velocities in the lower part of ablation and considerably higher ones in the middle and upper parts is characteristic feature of a glacier to surge which results in transportation of ice from higher to lower part (Meier and Post, 1969). Due to high sliding velocities, the basal ice must be at melting point during the surge (Paterson, 1983).

Vestre brogger and Midre loven glacier located at a distance of about 3 km in SW and 4.5 km in SE respectively from the Himadri (Indian Research Station at Arctic) are small valley glaciers. The geomorphic features formed by these small valley glaciers are lateral moraines, recessional moraines, hummocky moraines, out wash plains and kettles where poorly sorted sand, silt and gravels are deposited in thick succession (Fig. 2). Convex wrinkled surface, crevasses, bergchrunds, supraglacial streams, longitudinal debris strips, thrust moraines, convex longitudinal profile with breaks in slope, fractures and joints are the characteristic feature of the valley glacier (Singh and Ravindra, 2011). The moraines are made up of clast supported boulders. The cumulative percentage of sand, silt and clay is about 30% and boulders about 70%. The boulders varying in size from 2-10 cm are 50%, 10-15 cm 15% and more than 15 cm are 5%. The length, width, height and provenance of the moraines are changing with respect to the changing volume of glaciers due to climate change. Hummocky moraines produced by dumping and in glacial thrusting, are mound shaped complex moraines formed when the glacier was at its most dynamic stage. In the area mound shaped debris some with ice core can be observed. The hummocky moraines consist of about 20% sand, silt and clay and 80% boulders. A 65% of the boulders vary in size from 4-10 cm in length and 3-5 cm in width, whereas 10% boulders are 10-20 cm in length and only 5% boulders are more than 20 cm and up to 4 feet in length and 2 feet in width.

The azimuths of the orientation of the boulders were measured from morainic deposits for palaeocurrent analysis. The rose diagram prepared on the basis of boulder alignment is shown in (Fig. 3). The bi-modal rose diagram indicates two directions for the movement of the glacier in the past with a prominent direction in the S 61° W.

The out wash plain are reworked by surging glaciers and also by the processes which originate during deglaciation. A trench was made to find out the nature of the outwash plain deposits. The facies were documented and a litholog (Fig. 4) was prepared to see the vertical variation and the nature of sediments. The litholog indicate 5 facies of two events. In the first event at the base 20-28 cm thick poorly sorted matrix supported boulders are present. In which the size of boulders vary from 5-10 cm. This unit is underlain by 40-45 cm thick poorly sorted matrix supported boulders. The size of boulders varies from 3-5cm. This unit is underlain by 60-65 cm thick matrix supported granules, which is the top of first event. The decreasing size of boulders from base towards top shows the decreasing energy of the glacier and so the increase in temperature.

In the second event the lower unit is 5-6 cm thick granule with boulders which lies above the matrix

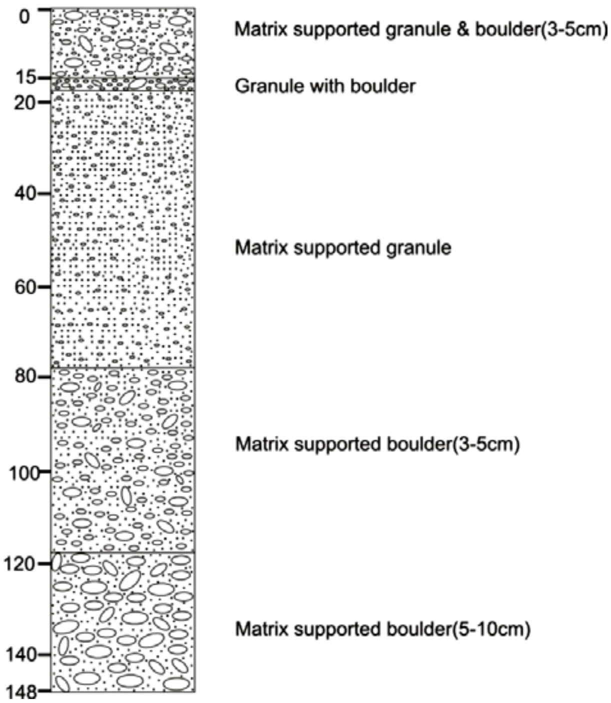

Fig. 4. Showing facies of the sandur deposits

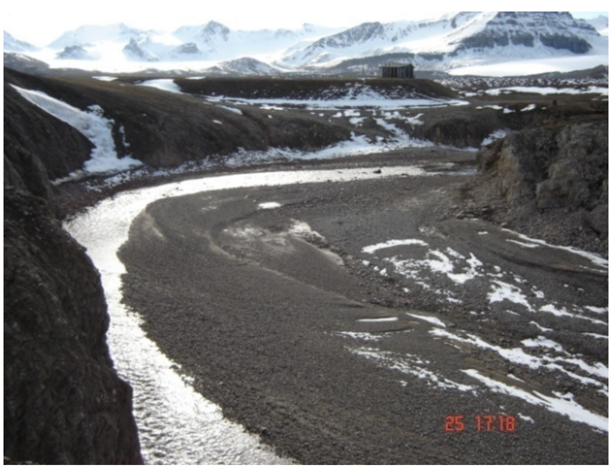

Fig. 5. Showing valley and channel of river originating from Vestre Brogger glacier

Fig. 6. Showing abandoned channel of river originating from Midre Loven glacier

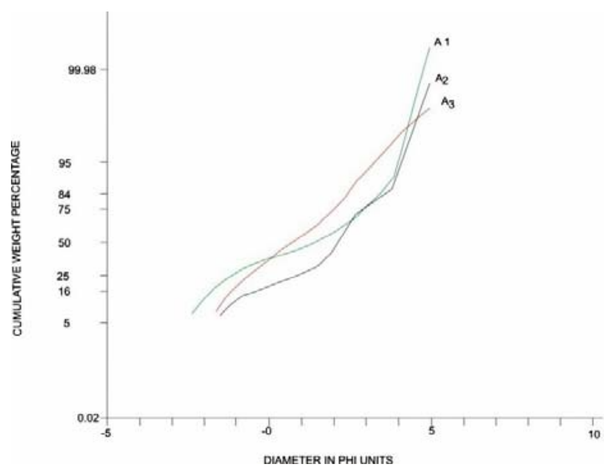

Fig. 7. Showing cumulative curve of granulometric analysis

TABLE 1

Grain size parameters

Sample No.	Mz	σ1	Sk1	KG
A1	1.06 φ	2.08 φ	-0.41	0.72
A2	1.77 φ	1.58 φ	0.18	1.14
A3	0.73 φ	1.62 φ	-0.28	0.91

(Where Mz is mean size, σ1 is inclusive graphic standard deviation, Sk1 is inclusive graphic skewness, and KG is graphic kurtosis).

supported granule of the first event. The top of second unit is 10-15 cm thick matrix supported boulders (3-5 cm in length) overlain the granule with boulders and shows the increasing energy of the glacier.

The ephemeral rivers transport large amount of sediments from mountain to the plain and to the ocean. Generally, the rivers originating from glaciers are large with high discharge and heavy sediment load but in this area snow fed rivers are very small 3-5 km in length only with low discharge and low sediment load. The valley width varies from 50-100 feet in which channels are 15-20 feet wide only (Fig. 5). The depth of the channel varies from 1-4 feet. The rivers carry bed load, suspended load, and dissolved load. The middle and distal part of the river

TABLE 2

Weight % of different grain size fractions of sediments

Mesh no.	φ scale	Weight (in gram)			Weight %			Cumulative wt. %		
		A1	A2	A3	A1	A2	A3	A1	A2	A3
10	-1.00	12.06	8.979	16.71	22.21	10.31	17.78	22.5	10.31	17.78
18	0.00	3.97	4.33	13.90	7.31	4.97	14.80	28.75	15.28	32.58
35	1.00	4.48	7.09	17.61	8.24	8.14	18.74	37.5	23.42	51.32
60	2.00	9.48	30.09	25.00	17.47	34.57	26.62	56.25	57.99	77.94
120	3.00	14.20	13.77	13.39	26.17	15.82	14.25	81.00	73.81	92.19
230	4.00	10.06	22.39	5.82	18.54	25.72	6.19	99.90	99.53	98.38

(Where -1 to 0 φ is very coarse sand, 0 to 1 φ is coarse sand, 1 to 2 φ is medium sand, 2 to 3 φ is fine sand, and 3 to 4 φ is very fine sand.)

exhibit sand bar deposits and small scale ripple marks. The river originating from the Vestre Brogger glacier drains into Kongsfjorden with a prominent delta whereas the Midre Loven drains with abandoned delta and now through an estuary (Fig. 6).

The position of the distributaries mouth bar of delta and estuary keeps on migrating due to sea level change and tectonic activity. The sediment samples were collected near origin (A1), middle reach (A2) and confluence of the river with ocean (A3) for granulometric analysis from the Midre Loven glacier. The granulometric parameters are given in Table 1 and the cumulative curve for the grain size is given in Fig. 7. Table 2 shows the weight percentage of the different grain size fraction of sediment.

3. Conclusions

The main sedimentary environment active for the formation of landforms and sediments are glacial during glacial stage, while during deglaciation many sedimentary environments came into existence and contribute in shaping the landscape of the area. The landscape of the Ny-Alesund, Svalbard, Arctic is carved by the last period of glacial activity followed by surface processes/sedimentary environments evolved during interglacial period under direct control of climate and tectonics.

Since the movement of most glaciers in this region is very slow, the front will shrink and retreat in periods between surges. The front position therefore gives little information on whether the ice mass is growing or shrinking. The convex shape and steep slope gradient near snout of the Midre loven and and Vestre brogger glacier with well marked frontal convexity indicate the surge features (Hagen, 1987 and Hagen & Liestol 1990) and tectonic control. The sandur facies in which the clast supported facies are followed by matrix supported facies which are further capped by clast supported facies also explain the decreasing and increasing energy of the glacial and so the glacial retreat and advance stages. The roses of palaeocurrent indicate that there are two directions for the movement of the glaciers in the past. It means the glacier was changing its direction frequently which explains the strong control of tectonic activity. The granulometric parameters indicate that the grain size decrease and again increases in the downstream direction which further supports the influence of the tectonic activity.

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