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Catastrophic events and types of environment in the north of West Siberia during the Pleistocene

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Abstract: This article deals with Pleistocene catastrophic events and describes the geological evidence for these catastrophs in the northern part of West Siberia. Main types of Pleistocene environments in this area are characterised. An association is discussed between catastrophic events and stratigraphical boundaries of the Pleistocene Period that reflect rapid and contrasting changes in palaeoenvironment. Palaeoenvironmental conditions as well as global and local factors controlling catastrophic events are outlined. The influence of climatic changes on the origin of natural catastrophs within the Northern Siberian Plains is suggested. The study of Pleistocene catastrophs is vital for a correct prognosis of modern negative factors and events in the area.

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INTRODUCTION

The Quaternary history of the northern part of West Siberia involves various events: glacial expansion and transformation of the bedrock relief, blocking of a free river drainage to the north from limnoglacial basins, glacio-isostatic movements controlled by progradation and degradation of ice covers, dust storms, marine transgressions, intensive cryogenesis, glaciofluvial erosion etc. Quaternary climatic changes in West Siberia controlled multiple changes in landscape borderlines as well as in the structure and composition of biotic zones.

MAIN TYPES OF PALAEOENVIRONMENT IN SIBERIA

It is generally accepted that during the Pleistocene the landscapes, similar to the modern ones, were common in West Siberia during interglacials (ARKHIPOV - VOLKOVA 1994). The climatic fluctuations are manifested by shifts of flora zone boundaries. On the other hand, significantly different environments periodically developed during glacial stages. The periglacial landscapes were dominated by a "mixed" tundra-steppe vegetation. The Quaternary geological sections record alternations of two main types that correspond to glaciations and interglaciations in North Siberia.

At the same time, there is evidence for a third "intermediate" type of palaeoenvironment (KAPLYANSKAYA - TARNOGRADSKIY 1978, SOLOMATIN 1986, ASTAKHOV 1992, 1995, ZOLNIKOV 1991a, b). For instance, buried isolated ice plateaus were preserved as relics of former glacier covers (Fig. 1). It is suggested that deglaciation in West Siberia started by dissection of the ice sheet by glaciofluvial streams into single major ice fragments. Some of those became dead ice fields covered by ablation and eolian deposits that prevented further ice melting. In North Siberia, cryolithozone conditions allowed the underground ice layers to be preserved during interglacials (KAPLYANSKAYA - TARNOGRADSKIY 1978, SOLOMATIN 1986). Buried ice plateaus appeared as typical landscape features at the end of glacials and persisted during interstadials or even interglacials.

They could have been eliminated in two principal ways: 1 – by ice infusion at the onset of a new glacial stage and 2 – by permafrost degradation controlled by climatic warming. With the permafrost degradation there was an activation of exogenous processes of relief development e.g. thermokarst with relief inversion (ASTAKHOV 1995). In some cases, areal denudation of deposits occurred over vast areas.

CATASTROPHIC EVENTS

The most characteristic catastrophic events of Pleistocene Siberia include flooding of low areas due to river damming by glaciers. There is evidence of high water level stands. An intact palaeosol in sections along the right bank of the lower Ob River, overlain by glaciolacustrine sediments of the Sartan (Late Weichselian) age (22–10 ka BP), indicates a very rapid rise of the water level due to formation of an ice-dammed lake.

Major catastrophic events took place during the ice-dammed lake outflow. Figure 2B shows erosion cuts within the unit of glacio-lacustrine clays of the Ermakovo (Early Weichselian) glaciation. The exposures formed by erosion of the unconsolidated silty-clay material after a break of the ice dam (ZOLNIKOV 1991). Their stratigraphy reveals the subaqueous and subaerial deposits of the Karginsk (Middle Weichselian) age (50–22 ka BP). Multiple breaks of ice dams during the Pleistocene resulted in the formation of buried valleys observable in the north of West Siberia reaching up to 200–300 m below the modern sea level.

Drainage of ice-dammed lakes was followed by intensive aeolian activity over vast areas unprotected by vegetation cover. As a result, the number and intensity of dust storms increased.

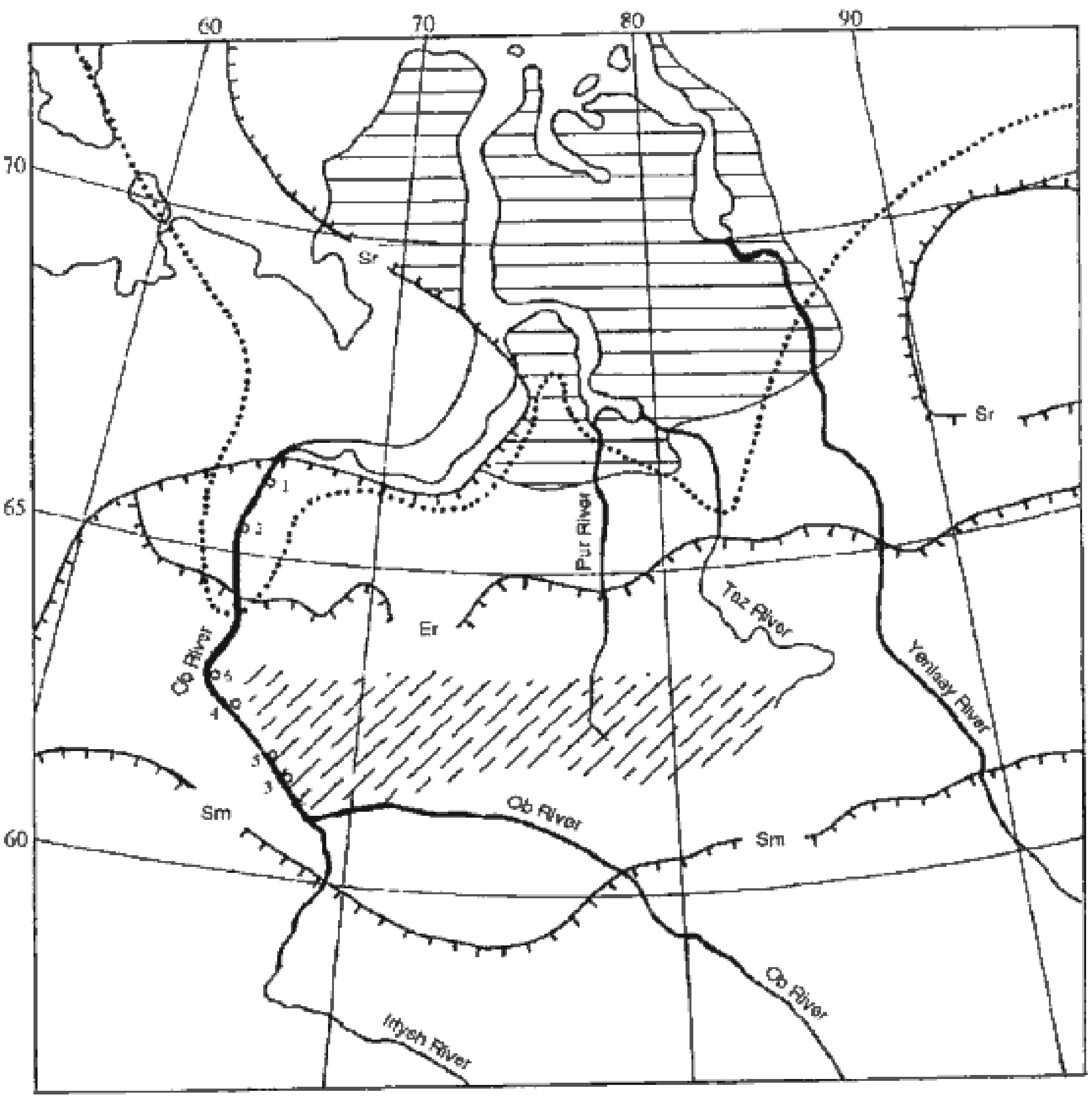
During the late glaciation erosion, cuts were intensively filled by fluvial deposits and mudflows (section 3 in Fig. 1, Fig. 2C).

Thus, a few types of catastrophic events are characteristic of glacial/interglacial transition periods: breaks of ice-dammed lakes, marine ingressions, wide-spread wind storms and processes of rapid filling of erosion cuts by fluvial and colluvial deposits.

Catastrophic events also occurred during interglacial stages. For example, high rates of sedimentation were associated with the Sanchung deposit accumulation in the northern Yenisey River basin due to redeposition of material by mud flows (SUKHORUKOVA 1975). As a result, "till-like" deposits are identified in marine series (ARKHIPOV - VOLKOVA 1994). The frequent occurrence of till-like deposits with microfauna *in situ* in the area of marine transgressions indicates intensive inundations of former glacial landscapes by sea water.

In some previous studies, a catastrophic pattern was identified for the initial degradation of the buried glacial relics during transitional interglacial conditions (ZOLNIKOV 1994). Figure 2D shows flow-till formations which are characteristic of the melting of subterraneous ice and the redistribution of saturated moraine materials in response to palaeorelief tilting. Depending on the degree of earth surface dissection and amount of ice within the palaeolandscape, in some cases, such impulse processes of permafrost degradation often led to either relief smoothing and compaction of deposits or an increase of relief contrast.

Degradation of buried ice was caused by changes of the regional distribution of permafrost at the expense of accumulation of long-lasting geothermal effects. A specific pattern of permafrost degradation depended on local conditions. In some cases the degradation had local manifestations dispersed throughout the area, in other cases degradation of a large relic glacial plateau covered vast areas. Areal denudation, at the expense of high



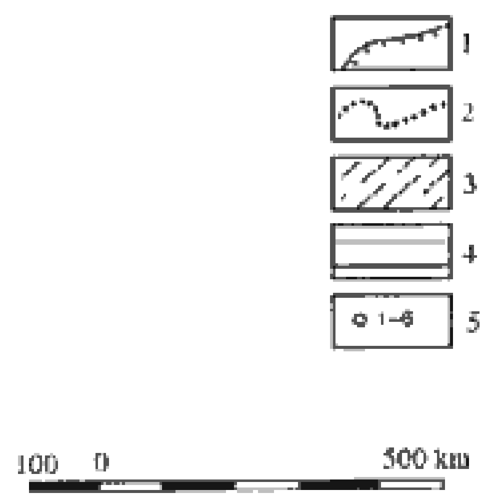


Fig. 1. Palaeogeographical peculiarities of the northern part of West Siberia.

1 – limits of the ice sheets (Sm – Samarovo, Er – Ermakovo, Sr – Sartan glaciations); 2 – limit of the Kazantsevo transgression; 3 – palaeozone of glacial relics of the Middle Pleistocene glaciation; 4 – transpolar zone of the buried ice of the Late Pleistocene glaciation; 5 – sections.

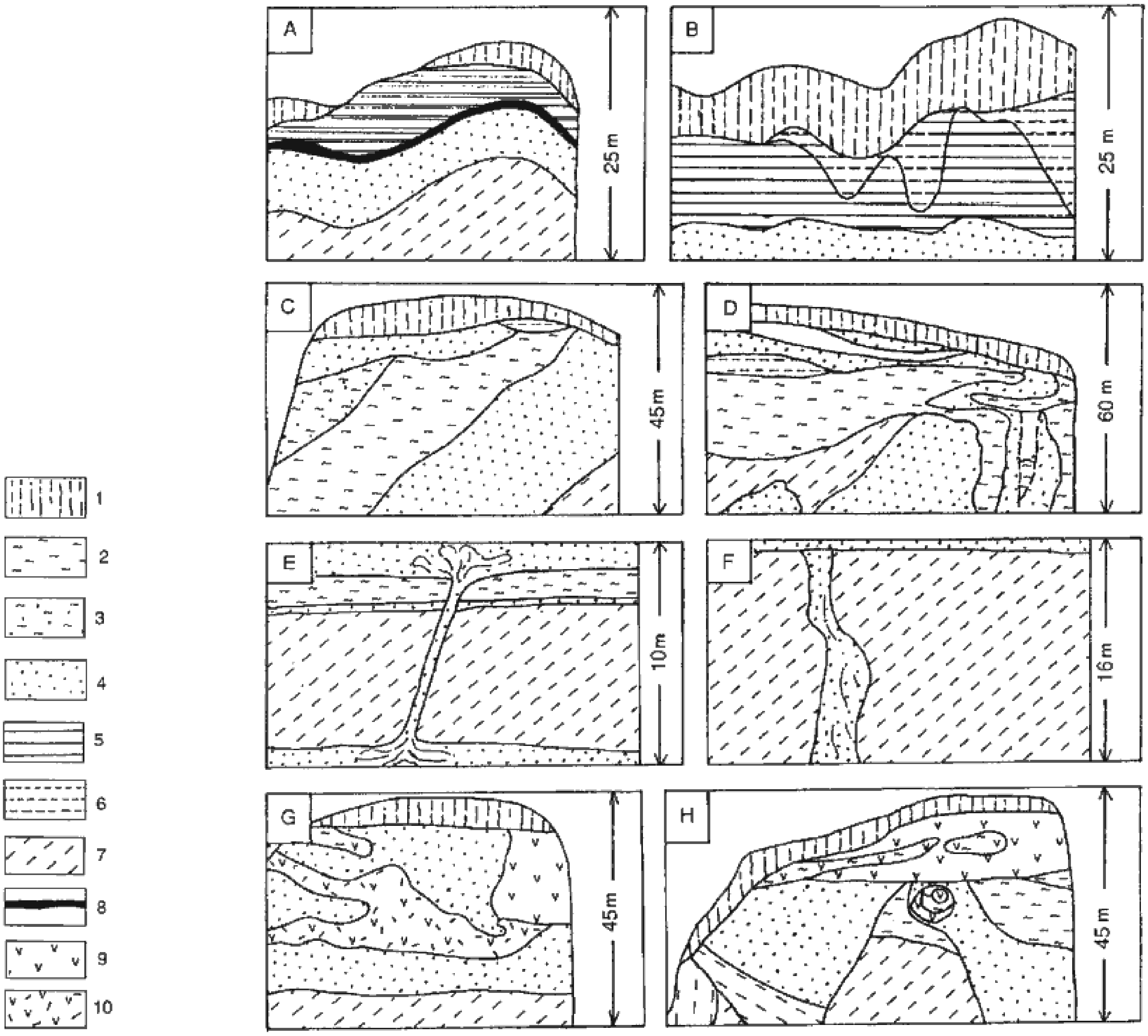


Fig. 2. Types of catastrophic events recorded in the Quaternary deposits. Lithology: 1 – subaerial deposits; 2 – flow till and till-lacustrine deposits; 3 – undissected mudflow deposits; 4 – fluvial deposits; 5 – glaciolacustrine deposits; 6 – lacustrine deposits; 7 – till; 8 – buried soil; 9 – pre-Quaternary clay; 10 – mixture of till and pre-Quaternary clay. Geological sections: A – paleosols overlain by glaciolacustrine sediments at the Pitlyar site (section 1 – Fig. 1); B – erosional gullies in glaciolacustrine sediments near the Gorka site (section 2 – Fig. 1); C – steep tilting layers deposited by water and mud streams in the Ob River section at the Urmannoye site (section 3 – Fig. 1); D – colluvial deposits at the Kormuzhihantka Yar site formed by melting of glacial relics during the thermal optimum of the last interglacial (section 4 – Fig. 1); E – "sand volcano" in the Samarovo glaciocomplex at the Sosnovo site (section 5 – Fig. 1); F – glaciotectonic dislocation at the Sosnovo site (section 5 – Fig. 1); G – glaciodynamical thrusts at the Sosnovo site (section 5 – Fig. 1); H – clay diapirism in the "Khalapantian Mountains" (section 6 – Fig. 1).

melting of the underground ice, apparently had a maximum distribution in the central and northern regions of palaeoglaciozones. In such areas, unprotected by vegetation, aeolian processes were most active.

An example is the Middle Pleistocene palaeoglacial zone of the Samarovo glaciation (Fig. 1), with widespread sandy and silty-sandy sediments. Within the outwash frontal plain, it is difficult to differentiate the deposits of the latter glaciation 200 ka BP) from fluvioglacial and postglacial Shirta (190–130 ka BP) catastrophic fluvial deposits.

Apart from the above, other Pleistocene catastrophic events deserve attention. One of them is a "sandy volcano" cutting the Middle Pleistocene Samarovo glaciocomplex (Fig. 2E). Discolations are represented by subvertical and steep-tilting cracks filled up with a sand underlying the moraine unit. Their genesis is associated with moraine degradation during melting of the dead ice block under the till. The uneven load was caused by the non-uniform thickness of the overlying glaciogenic unit and the variable palaeorelief at its base. The hydraulic type of "sand volcanism" is evidenced by the fact that in fissures alongside the multiangled clusts of loam, there were also bands which reflect a paste-like state of the infrafissure mass during the overload-generated pressure eruption. This type of deposit dislocation differs significantly from glaciotectonic loads (Fig. 2F) which were developed directly underneath the glacier due to glaciodynamical thrusts (Fig. 2G). Glaciodynamical and glaciotectonical dislocations affected the main moraine. However, in contrast to the postglacial "sandy volcano", the glacial deposits are cut by fluvioglacial sediments and overlying flow-tills. A postglacial dislocation (Fig. 2E) usually transects the entire glaciocomplex.

Dislocations of the "volcanic" type are principally associated with the melting of the Middle Pleistocene underground ice during the Kazantsevo (Eemian) interglacial. "Sandy volcanoes" are coeval with the upper fluvial layers. Figure 2H shows one of the sections with a clay dislocation. The Palaeogene clays here occur directly beneath the loess-like loam on the top of the section. Sands are also affected by postglacial dislocations. A spiral dislocation is observable within the layers of the sandy till material and clays. All those dislocations are of a postglacial age.

The above described "sediment-volcanism" (both sandy and clayey) provide evidence for degradation of a buried glacial plateau in the Middle Pleistocene palaeoglacial zone. These processes were coeval with the accumulation of fluvial deposits of the Kazantsevo (last interglacial) climatic optimum (125 ka). The main stage of destruction of buried glacial plateaus was much younger, because the relics of the Ermakovo glaciation (100–50 ka BP – see Fig. 1) persisted into the Holocene optimum (Astakhov 1995).

In conclusion, catastrophic events of various types and manifested at different time and degree of intensity, occurred in many regions under specific geo-historical and palaeogeographical conditions. The termination phases of glacial stages are rich in catastrophic events of global, regional and local significance. However, major catastrophs happened also during interglacials.

ENVIRONMENTAL PREDICTION FOR NORTH SIBERIA

One of the main objectives of environmental studies is to determine possible regional reactions to the global climatic changes. Global climatic warming is comparable with the previous climatic optima. Therefore, it is reasonable to consider the thermal maxima of the Late Cenozoic and the present one as the first impulses of the same type which could precipitate activation of the events described above.

In the transpolar region, buried ice is still widely distributed. Usually it is located inside the ridges of accumulative-inversional glaciorelief. On the seaside plains, relics of buried ice often reach 20–30 m in thickness and occur directly under the deposits of marine and lacustrine terraces as on the Yamal and Gydan Peninsulas.

Regional climate warming and the economic development of North Siberia have had a number of catastrophic side-effects on landscape, biota and population which have past geological analogies, such as large-scale erosion and gully formation, areal destruction of tundra landscapes, sand dune formation, activation of a local ground ice merging, etc. Most regions revive exogenous lithogenesis processes, characterized by areal relief sinking due to uncompensated oil and gas extraction. Exotectonic movements are also observed; they are caused by failure of the heat-water exchange regime in the permafrost and long-term frost units.

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