CONDITIONS OF PEAT FORMATION

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Contents

Summary

Peat formation and development are mainly controlled by the combined conditions of water and temperature. On Earth, temporal and spatial changes of water and temperature depend upon climatic conditions, and geological, geomorphologic, and hydrological factors. These factors directly and indirectly influence peat formation, development, and its characteristics.

Among the climatic factors, temperature and humidity are the most important factors that control the decomposition, and the transformation of organic debris. Geographical and geomorphologic factors relocate the water, and the heat. Slowly sinking crustal movement is beneficial to peat accumulation, as negative landforms are more conducive to peat development than positive landforms. Zonality and azonality of hydrological factors play an important role in determination of the zonal and azonal distribution of peat. Soil conditions, including soil microbes, soil temperature, soil humidity, and pH

value, directly influence the decomposition degree of organic debris, thereby influencing peat formation.

Peat is the material which is created and transformed within mires, formed only when the accumulating quantity of organic material is greater than the decomposing quantity. Different combined conditions of water and temperature decide the balance between accumulation and decomposition of peat, i.e. its accumulative rate, and the ecological characteristics of peat bogs. Temporal and spatial changes of water and temperature primarily depend on climatic condition, then geological factors, geomorphologic factors, and hydrological factors.

1. Climatic Factors

Different combined conditions of climatic factors, especially of humidity and temperature, decide the characteristics of the interaction between the organic and inorganic world, and decide the interchange of matter and energy, thereby controlling the decomposition and transformation of organic debris.

1.1. Influence of Temperature on Peat Formation

Temperature influences plant growth rate, and the resulting biomass. In different temperature climatic zones, not only the plant species and rates of production are different, but also the accumulative quantity of plant debris is different (see Table 1).

Zone	**Accumulative quantity (Dry weight) (t (km^2)$^{-1}$ • a^{-1})**	**Decomposition capacity (t (km^2)$^{-1}$ • a^{-1})**	**Average temperature of the warmest month (°C)**
Polar tundra zone	0.3	Extremely weak	<0.0
Tundra zone	1.4	Slight/weak	7.2
Coniferous zone	8.0	6.0	17.0
Broadleaf forest zone	9.0	7.5	18.5
Forest steppe zone	10.0	10.0	21.0
Grassland zone	5.0	11.0	22.0
Grassland desert zone	2.0	14.0	25.0
Temperate desert zone	0.2	17.0	28.0
Sub-tropical desert zone	0.4	17.5	28.5
Sub-tropical forest zone	11.0	15.0	25.5
Tropical savanna	6.0	16.0	27.0
Seasonal rainforest	13.0	15.0	26.5
Tropical rainforest	16.5	15.0	26.0

Source: Chai Xiu 1990

Table 1. Accumulative quality and decomposition capacity of plant debris in different natural zones.

Table 1 shows that the accumulative quantity of plant debris increases from the polar tundra zone to the forest steppe zone, and decreases largely from the forest steppe to the temperate desert due to aridity. But in sub-tropical forest zones the accumulative quantity of plant debris increases markedly, and in tropical rainforest zones the accumulative quantity of plant debris reaches its maximum. This changing trend of accumulative quantity of plant debris in different natural zones is mainly controlled by temperature and water availability.

Temperature influences the activity and reproductive capacity of soil microbes, thereby influencing the decomposition rate (or decomposition capacity) of plant debris. Under a cold climate, the soil microbes act weakly, so that plant debris decomposes slowly. Under higher temperature conditions, chemical action is stronger and the soil microbes reproduce quickly, so that decomposition of plant debris is accelerated. In the different temperature zones, the decomposition rates of plant debris are different (see Table 1.) Table 1 clearly shows that the decomposition capacity of plant debris increases from the polar regions to the tropical zones. Among these zones, the decomposition capacities of temperate and sub-tropical desert are the highest (but only from the temperature angle).

1.2. Influence of Water Availability on Peat Formation

Temperature and water not only influence the growth of vegetation, but also limit the activity of soil microbes. The water availability of a region is often expressed as the moisture coefficient (or conversely the aridity). The global distribution of peat coincides with areas where the annual average precipitation is higher than the annual average evaporation. If the moisture coefficient is very large, it is not only depressions and hollows that are conducive to peat accumulation, but even slopes and smooth watersheds can support development of blanket bog. Soil water has a strong influence on the activity of microbes. Microbial decomposition acts most strongly at 60% to 80% soil saturation. It is slower when water is limiting and also under conditions of saturation.

1.3. Actions of Combined Conditions of Water and Temperature on Peat

For peat formation, different combined conditions of water and temperature have different actions and results. M.M. Kononova and colleagues, scientists of the former Soviet Union, measured the value of carbon-dioxide emissions from soil, and studied the relation between the activity of soil micro-organisms, and the rate of decomposition of organic debris under different conditions of water and temperature. They found:

- When the soil temperature is 30ºC, and soil water is at 60–80% of saturation, the decomposing intensity of soil organisms is highest, and the value of carbon dioxide emissions from the soil reaches its maximum
- When the temperature and soil moisture both increase or decrease, the decomposing intensity decreases.
- If the soil temperature increases but soil moisture decreases, the decomposition intensity of soil organisms decreases.
- Similarly, if temperature decreases and soil moisture increases, decomposition also decreases.

1.4. Influence of Climatic Conditions on Global Peat Distribution

Due to climatic zonality, the combined conditions of water and temperature are different in different zones:

- Tundra zone: Due to the low temperature, the rate of plant growth quantity is low, but the decomposition of organic debris is also very weak, allowing plant material to accumulate. Peat development is therefore widespread, but its accumulative intensity is low, and the peat layers are consequently thin.
- Temperate coniferous and deciduous forest zone: In a temperate and wet climate, plants grow strongly—at least seasonally—but, under appropriate conditions of geology, geomorphology and soil chemistry, the decomposition rate of organic debris can be very slow. Locally, therefore, peat can develop very well; the accumulative intensity can be high, and the peat layers relatively thick.
- Tropical rainforest zone: With high temperature, high rainfall and a humid climate, plants grow very well. Though the decomposition of organic matter is very strong, the accumulating quantity of organic debris can be larger than the rate of decomposition, so allowing peat to develop.

2. Geological and Geomorphologic Factors

Geology has a major impact on peat formation, both through its influence on soil chemistry and regional and micro-climatic conditions. Peat will only develop where the water supply has a low mineral content and low levels of nutrients. Such conditions prevail if most of the water supply comes directly from rainfall. If much of the supply comes from groundwater, peat development is poor if the water has drained through deposits rich in calcium and magnesium. If, on the other hand, the rocks through which the incoming water has passed, have low levels of soluble minerals and weak buffering capacity, the resulting low pH and low levels of minerals and nutrients create an unfavorable environment for bacteria and fungi dependent on decomposition of plant material. Under these conditions, peat will readily accumulate.

Similar conditions of low pH and levels of minerals and nutrients can develop from the accumulation of aquatic vegetation in a lake. With poor water circulation and low levels of oxygen, the decomposition of plant debris can be very slow. As it accumulates the surface of the vegetation is gradually raised above the prevailing lake and groundwater level. If rainfall is sufficiently high, the continuous downward filtration ensures that pH is low and minerals and nutrients are in short supply. In time a convex profile develops, with the most acidophilic vegetation being on the higher ground in the middle. This is known as a raised bog.

The relief of the Earth’s surface has a huge effect on temperature and water availability, particularly through altitude and aspect. In the northern hemisphere, north-facing slopes are colder and wetter than south facing slopes; they are correspondingly more likely to support conditions favorable for peat formation. Such factors tend to displace climatic conditions, making their distribution, and the distribution of peatland, much more complex.

Geomorphology influences conditions for peat formation through its influence on hydrology, soil saturation, surface water movement and surface erosion. These changes directly or indirectly control the combined conditions of water and temperature, thus controlling peat formation and development. Peat will never accumulate where there is surface erosion, as the plant debris is washed away rather than accumulating.

2.1. Influences of Tectonic Movements on Peat Formation

Slowly sinking crustal movements are conducive to peat accumulation. Generally speaking, if the crust rises, erosion increases and groundwater level drops, creating a situation not beneficial to peat formation. If, on the other hand, the crust sinks rapidly, intensive sedimentation can occur and this too is detrimental to peat development. So it is only when the crust slowly sinks or keeps relatively stable, that surface erosion is weak, sedimentation does not occur and a suitable environment is created for peat formation in low lying areas. If the sinking rate of the crust is close to the rate of peat accumulation, very thick peat layers may form.

The depth of peat layers are heavily influenced by the frequency and rate of uplift, and likewise subsidence, as a result of tectonic movements. Some of the deepest peatlands have developed under the influence of tectonic sinking.

For example, the Siberian lowland is the largest peat accumulation area in the world. Throughout the Quaternary Period, the Siberian lowland continuously sank accumulating deep lacustrine–alluvial deposits, so that it became the largest plain in the world, with an area of 274.5×10^4 km^2. Many lakes are scattered about this smooth plain whose average slope is only 0. 0002 m km^{-1}.

Large areas of the plain surface accumulate water, and it is difficult for the water to drain away. Furthermore, the climate is very cold and wet. These conditions are beneficial to peat formation, and its accumulation, so it forms a huge peat accumulative area, whose reserves comprise about 20% of the total reserves of global peat.

Today, this area is still sinking at 10–15 mm per year, and peat bog is also continuously spreading. Elsewhere, such as in parts of the western coastal zone of Europe and the eastern coastal area of North America, peat has also developed well due to the climate and geology, and the favorable influence of tectonic and isostatic movements.

Large areas of peatland have developed on basalt plateaus and tablelands with spilling magma, as a result of the lack of fractures in the surface rocks, small inclination, and low permeability. An example of these conditions is provided by the Fusun and Jinyu area of the Changbaishan Mountain, China. The peatlands of the Japanese uplands are also mainly located in volcanic regions.

Peat often develops in crater lakes and lava dammed lakes, such as the Qingtongyang peatland of Haikang County, and the Tianyang peatland of Xuwen County in Guangdong Province, China. These are both crater lake peatlands.

There are reports of peat development in various areas where there has been recent volcanic activity, such as Kamchatka, the Pacific coast of North America, Tierra del Fuego, the Faeroe Islands, Norway, Switzerland, etc.

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Bibliography

Chai Xiu (1990) *Peat Geography* (in Chinese), 187 pp. Beijing: Scientific Press. [This work deals with peat characteristics, physical and chemical properties of peat, peat-forming conditions, and peat distribution.]

Chen Enjian (1959). *Soil Organic Matter* (in Chinese; the original version is in Russian). Beijing: Scientific Press.

Li Lianqing (1987). *Exploitation and Utilization of West Siberian Peat* (in Chinese; the original is in Russian), *Foreign Peat Geology*, 1, 76–78. Beijing: Scientific Press.

Sakakuchi (1983). *Peatland Geography—Research on Environmental Changes* (in Chinese; the original version is in Japanese) (trans. Liu Zheming et al.), pp 1–3, and pp 9–10. Beijing: Scientific Press. [This work provides the concepts of peat and peatland, peat characteristics, peat distribution and peat utilization in the world; it also deals with the relations between peat formation and natural environment.]

Yin Shanchun et al. (1991). *Peat Resources and Utilization in China* (in Chinese), pp 57–59. Beijing: Scientific Press. [This work describes the forming conditions, reserves, distributions, utilization and protection of peatlands in China.]

Song Haiyuan et al (1985). *Formation and Evolution of Peatlands in Xizhang Plateau*. *Geographic Science*, 5(2): pp 173–178. [This paper deals with the forming conditions and the Holocene peatland development in Xizhang Plateau.]

Zhong Jinyue & Zhang Zheyou (1981). *The Buried Peat in the Littoral Areas of China and the Paleo geography*, *Oceanologia et Limnologia Sinica*, 12(5), 412–421. [This paper deals with the distribution characteristics in the coastal areas of China and the paleogeography of buried peat.]

Biographical Sketch

Prof. Liu Xintu was born in 1936. In 1959 he obtained his bachelor's degree in geographic education at Northeast Normal University, Changchun City, China. From 1962 to 1972, he taught in the Northeast Normal University. From 1972, he has been working in Changchun Institute of Geography, Chinese Academy of Science, and was appointed as the president of Changchun Institute of Geography. He is also a member of the *Oceanic and Limnologic Society of China*, and the Vice-President of the Peat Society in the Jilin Province. His research is mainly on the mire eco-environment, and its rational utilization ways. He has undertaken investigation of mire and peat resources in the Sanjiang Plain, research on comprehensive exploitation models on peatlands, and adjustment and controlling measures on water and soil in peatlands. He has co-edited several books in Chinese, such as *Mires in the Sanjiang Plain*, *Research on Mires in China*, etc. He has also published about 50 papers in Chinese as well as international journals.