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D1.3.1 Reference permafrost map from historical sources

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission)	X
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

SUMMARY

A reference permafrost map has been developed based on historical data.

The map was created basing on paper permafrost maps published from 1970 to 1988. Practically it is a collection of five different maps (for Russia, Mongolia, China, Canada and Alaska) that are difficult to merge because of differences in permafrost thickness and temperature classification. In order to create digital maps paper maps have been scanned and digitized using ArcGIS software. The result data is shapefiles representing permafrost boundary, permafrost depth, temperature of permafrost and active layer thickness.

The link to data: ftp://ftp.niersc.spb.ru/Monarch_A/PermafrostMap.zip

MONARCH-A CONSORTIUM

Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Nansen Environmental and Remote Sensing Center	NERSC	NO
2	The University of Sheffield	USFD	UK
3	Universität Hamburg	UHAM	NO
4	Centre National de la Recherche Scientifique	CNRS	FR
5	Scientific foundation Nansen International Environmental and Remote Sensing Center	NIERSC	RU
6	Universitetet i Bergen	UiB	NO
7	Danmarks Tekniske Universitet	DTU	DK
8	Institut Francais de Recherche pour l'Exploitation de la Mer	IFREMER	FR

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1 Introduction

Permafrost is a layer of soil or rock, at some depth beneath the surface, in which the temperature has been continuously below 0 °C for at least some years. It exists where summer heating fails to reach the base of the layer of frozen ground. Most permafrost is located in high latitudes (i.e. land close to the North Pole), but alpine permafrost may exist at high altitudes in much lower latitudes. Permafrost accounts for 0.022% of total water and exists in 24% of exposed land in the Northern Hemisphere.

Permafrost will typically form in any climate where the mean annual air temperature is less than the freezing point of water. Exceptions are found in moist-wintered forest climates, such as in Northern Scandinavia and the North-Eastern part of European Russia west of the Urals, where snow acts as an insulating blanket. The bottoms of many glaciers can also be free of permafrost. Typically, the below-ground temperature will be less variable from season to season than the air temperature, with temperatures tending to increase with depth. Thus, if the mean annual air temperature is only slightly below 0 °C (32 °F), permafrost will form only in spots that are sheltered — usually with a northerly aspect. This creates what is known as **discontinuous permafrost**. Usually, permafrost will remain discontinuous in a climate where the mean annual soil surface temperature is between -5 and 0 °C. Discontinuous permafrost is often further divided into **extensive discontinuous permafrost**, where permafrost covers between 50 and 90 percent of the landscape and is usually found in areas with mean annual temperatures between -2 and -4 °C, and **sporadic permafrost**, where permafrost cover is less than 50 percent of the landscape and typically occurs at mean annual temperatures between 0 and -2 °C. At mean annual soil surface temperatures below −5 °C (23 °F) the influence of aspect can never be sufficient to thaw permafrost and a zone of **continuous permafrost** forms. In areas of continuous permafrost and harsh winters the depth of the permafrost can be as much as 1493 m in the northern Lena and Yana River basins in Siberia (Russia).

Overlying permafrost is a thin **active layer** that seasonally thaws during the summer. Plant life can be supported only within the active layer since growth can occur only in soil that is fully thawed for some part of the year. Thickness of the active layer varies by year and location, but is typically 0.6–4 m thick.

Since we observe a number of evidences of climate warming it is natural to expect and it has been shown already in different publications that permafrost thaws and its boundary retreats northward. In the frame of the task 1.3 of the MONARCH Project a reference permafrost map has been developed based on historical data that can represent the state of permafrost before the period of contemporary warming (the 1980s).

2 Permafrost map of Russia

In order to find a best representation of permafrost in Russia in 70-80s of the previous century, NIERSC has created Russian historical permafrost map data collection containing 317 maps. About 50% of the collected maps were created in 1980s. Maps of global coverage are of very coarse resolution. Most maps are for limited areas of Russian Federation, but some of them are for the territory of the former Soviet Union or Russia as a whole. Comparison of the collected maps has demonstrated some differences in permafrost description. There has been done evaluation of the collected maps quality, taking into account comprehensiveness and the scale of the maps, permafrost parameters availability and standing of the map's author in the scientific community. As a result of that evaluation one permafrost map has been selected to be a base map for digitizing.

Digital permafrost map of Russia has been created on the base of the map developed by I.Baranov in 1970. It is a paper map of quite a big size with a scale of 1 : 5 000 000.

The map was scanned sheet by sheet. Then every sheet has been georeferenced. Illustration of the process is shown in Figure 1.

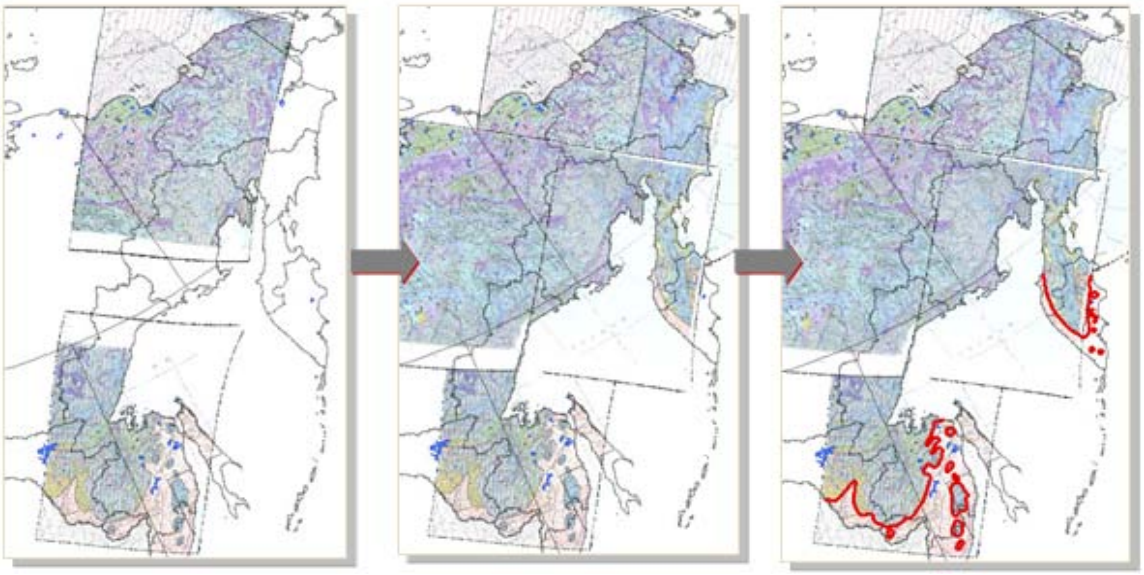

Figure 1: Georeferencing of the scanned sheets of the permafrost map of Russia.

The following parameters of the permafrost has been digitized:

- permafrost boundary,
- permafrost depth (contours for 25 m, 50 m, 100 m, 200 m, 300 m, 500 m, 700 m and 900 m),
- temperature of permafrost,
- active layer thickness.

Figure 2 shows all the digitized parameters. The first three of the listed earlier parameters are digitized as line shapefiles, and the last (active layer depth) has been presented on the map as a point file and digitized correspondingly.

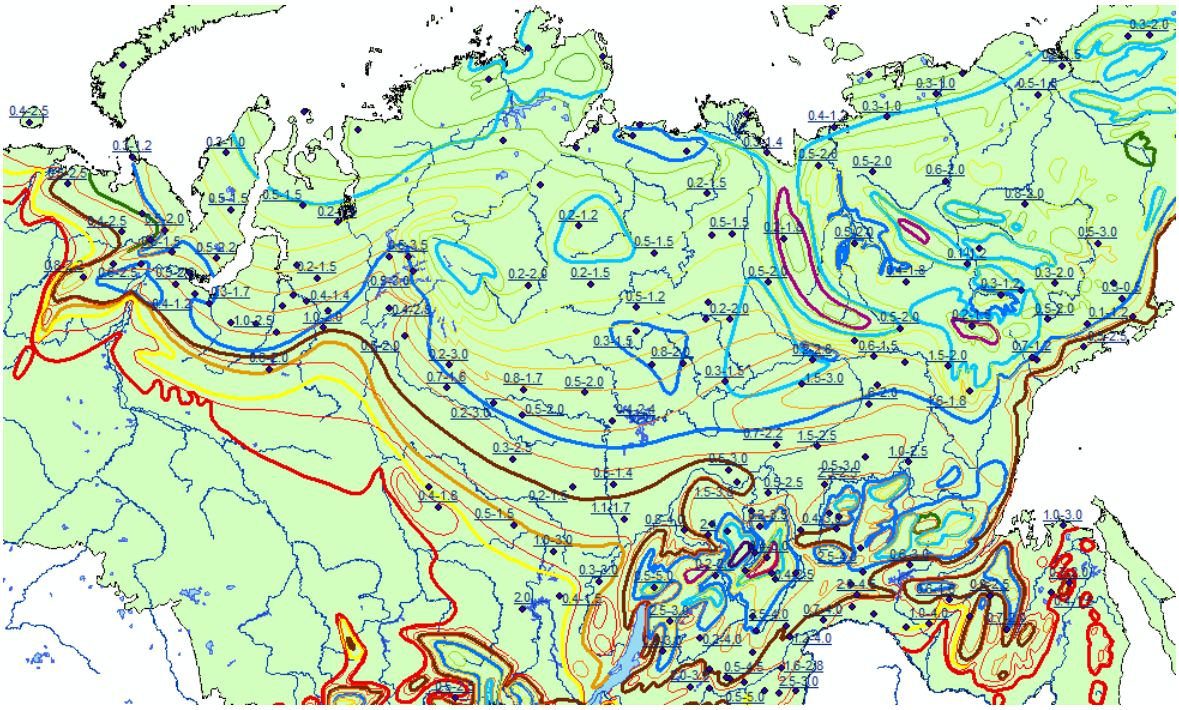

Figure 2: Digital permafrost map of Russia. Digitized parameters: permafrost boundary, depth, temperature and active layer.

3 Permafrost map of Mongolia

Digital permafrost map of Mongolia has been created basing on the paper map developed by S.Zabolotnik in 1972, scale 1 : 4 500 000. The paper map has been scanned and georeferenced, the result is illustrated by Fig. 3.

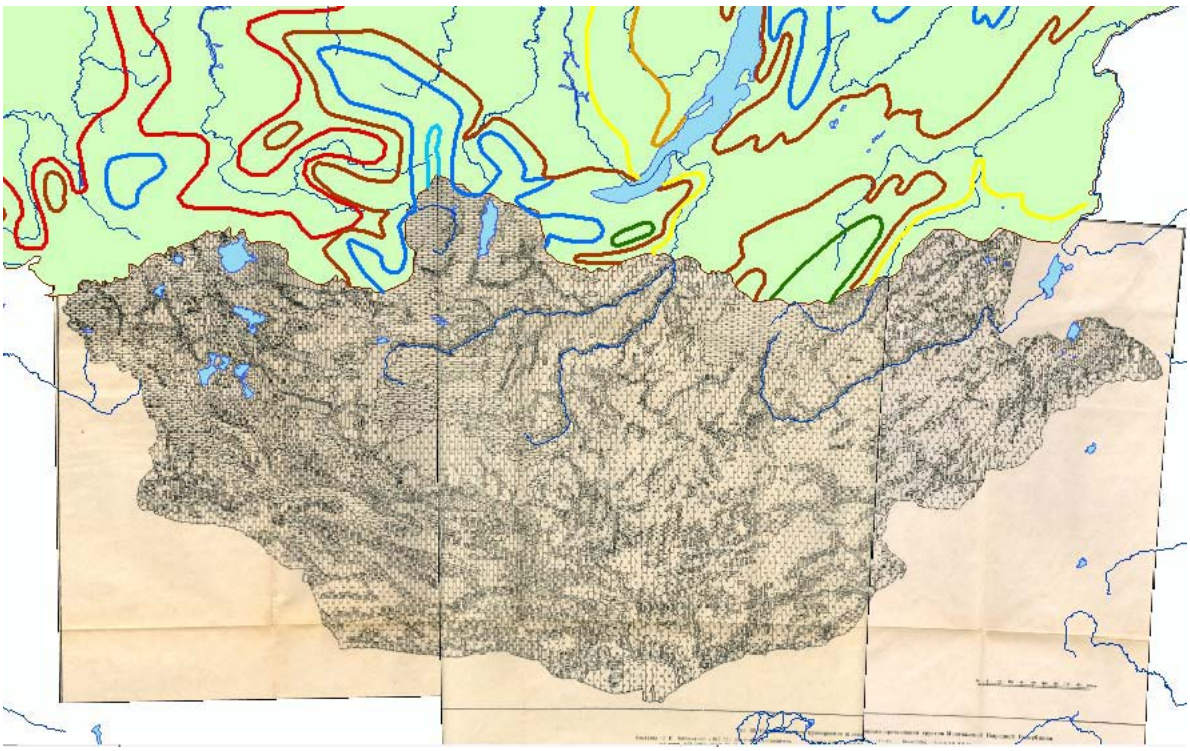

Figure 3: Scanned and georeferenced permafrost map of Mongolia. Three sheets are brought together.

On the Mongolia permafrost map the permafrost depth is described by the intervals:

- < 50 m,
- 50 – 100 m,
- > 100 m,

which is different from the description of the same parameter on the Russian permafrost map, where the same parameter has been described by integer values.

For the permafrost temperature there are only two values to describe the parameter: 0 and 2° C. They are shown as isoterms (lines). The active layer is described similar to the way it has been described on the Russian permafrost map – as a point file.

Figure 4 shows the results of digitizing. It also illustrates problems with matching data for different territories – Russia and Mongolia. There is obviously a problem of edge matching.

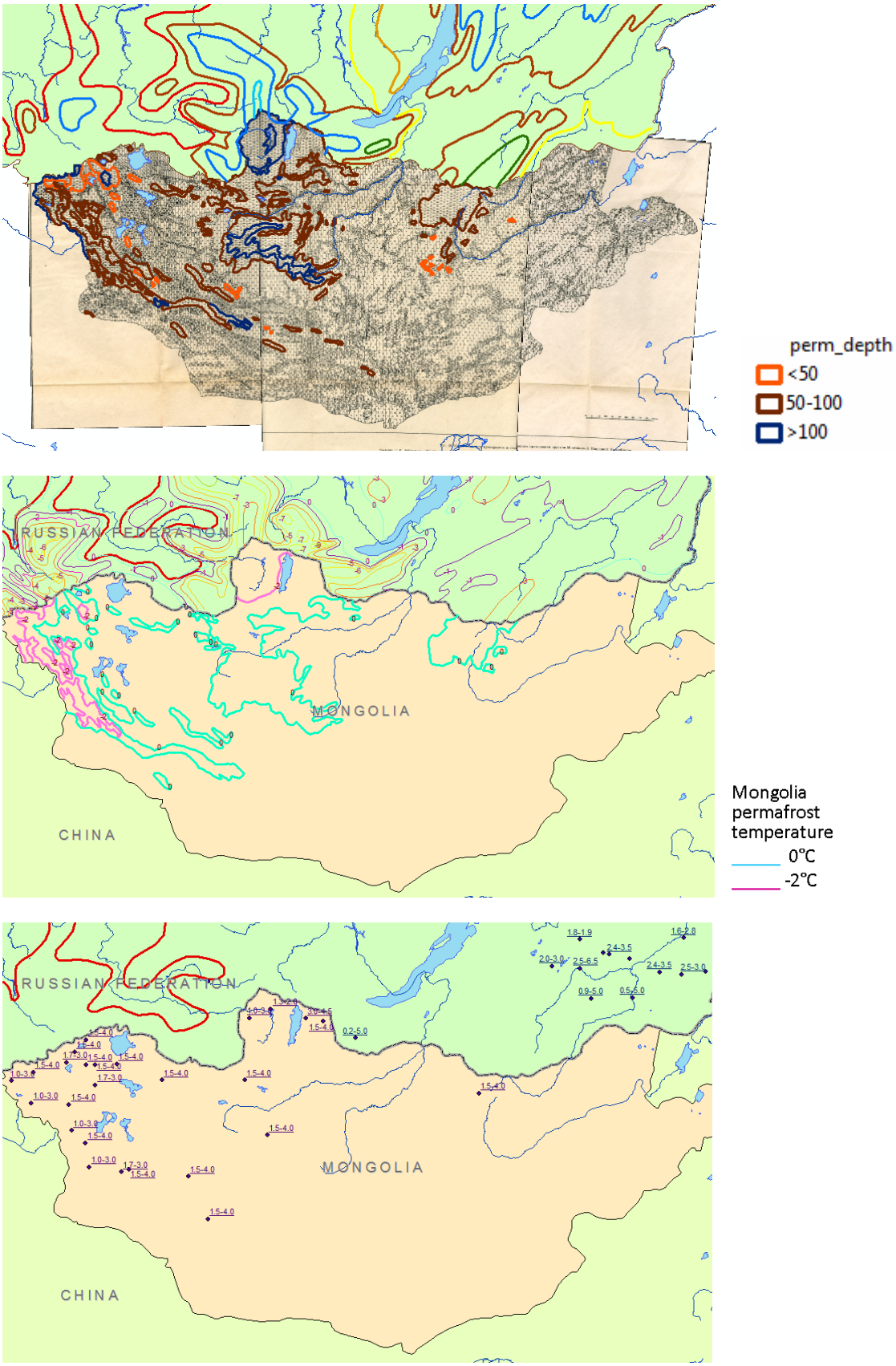

Figure 4: Permafrost map of Mongolia layers: depth of permafrost, temperature and active layer thickness.

4 Permafrost map of China

Digital permafrost map of China has been created basing on the paper map "**Map of snow, ice and frozen ground in China"** compiled by Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, published by China Cartographic Publishing House, Beijing, in 1988. The map scale is 1 : 4 000 000.

Parameters mapped are the following:

1. High-latitude permafrost in Northeast China: Predominantly continuous permafrost, Permafrost with isolated taliks, Isolated permafrost

2. High-altitude permafrost:

   Plateau permafrost – Predominantly continuous permafrost, Isolated Permafrost
   Alpine permafrost - AltayMountains, Tianshan Mountains, Qilian Mountains, Hengduan Mountains,Himalaya Mountains, Changbai Mountains, Mount Huanggangliang, MountTaibai

3. Non-Permafrost: Seasonal frozen ground, Instantaneous frozen ground, Unfrozen ground

Boreholes with the measurements of ground temperature, mean annual ground temperature, and thickness of permafrost are presented by their locations (by points).

The base map after it was scanned and georeferenced is shown in Fig. 5.

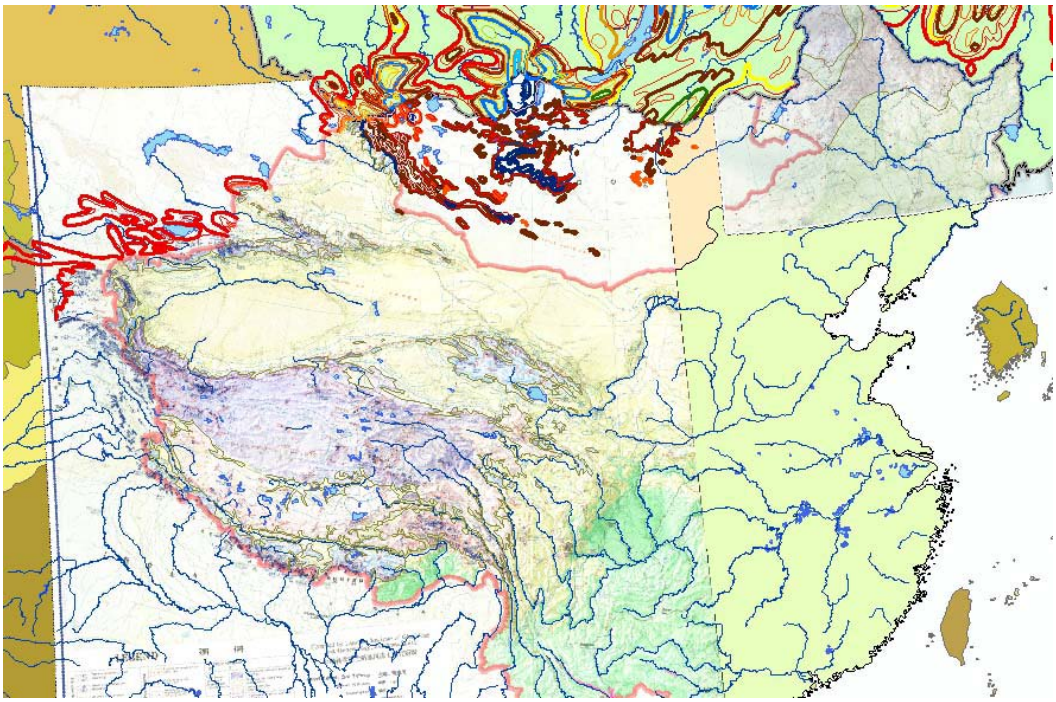

Figure 5: Paper permafrost map of China scanned and georeferenced.

Pemafrost zones shown in the map are described in terms of the percentage of the permafrost as follows:

- Predominantly continuous permafrost (PCP): 80-65%
- Permafrost with isolated taliks (PIT): 60-50%
- Isolated permafrost (IP): 30- 5%
- Alpine permafrost (AP): 80-20%

Digitized permafrost zones and points where temperature and thickness of permafrost have been measured are shown in Fig. 6.

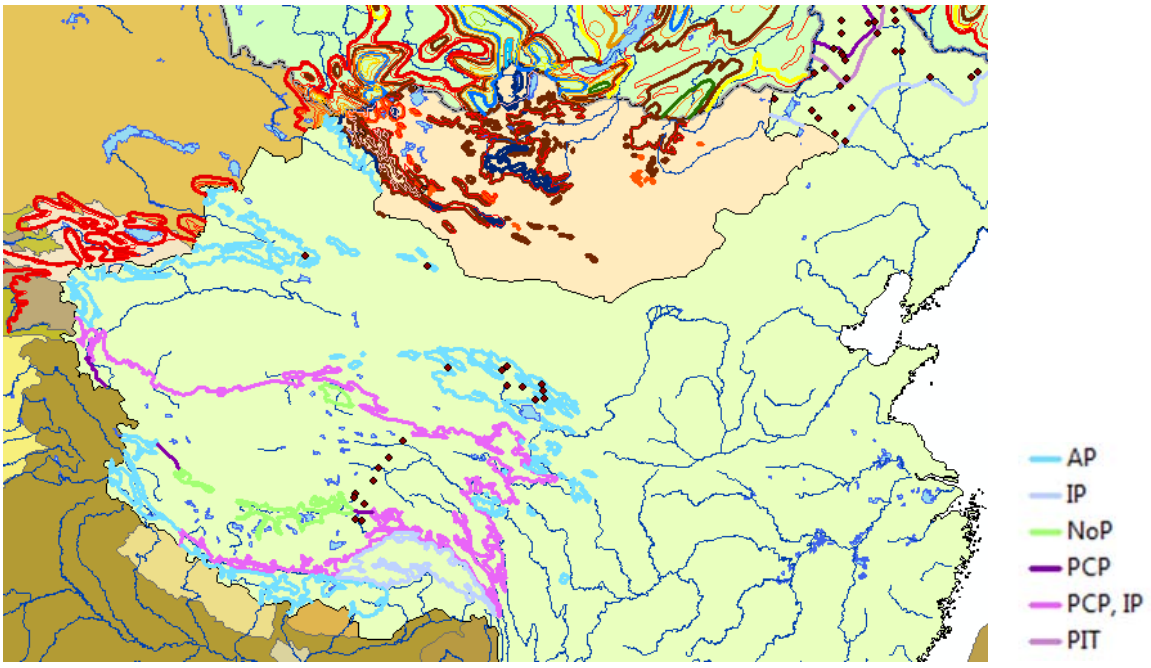

Figure 6: Permafrost zones in China and boreholes with the measurements of ground temperature, mean annual ground temperature, and thickness of permafrost as points.

5 Permafrost map of Canada

Base permafrost map of Canada for the time before global warming had started was found on the Internet in The National Atalas of Canada, 1973. The link to the data is:

http://atlas.nrcan.gc.ca/auth/english/maps/archives/4thedition/environment/land/011_12

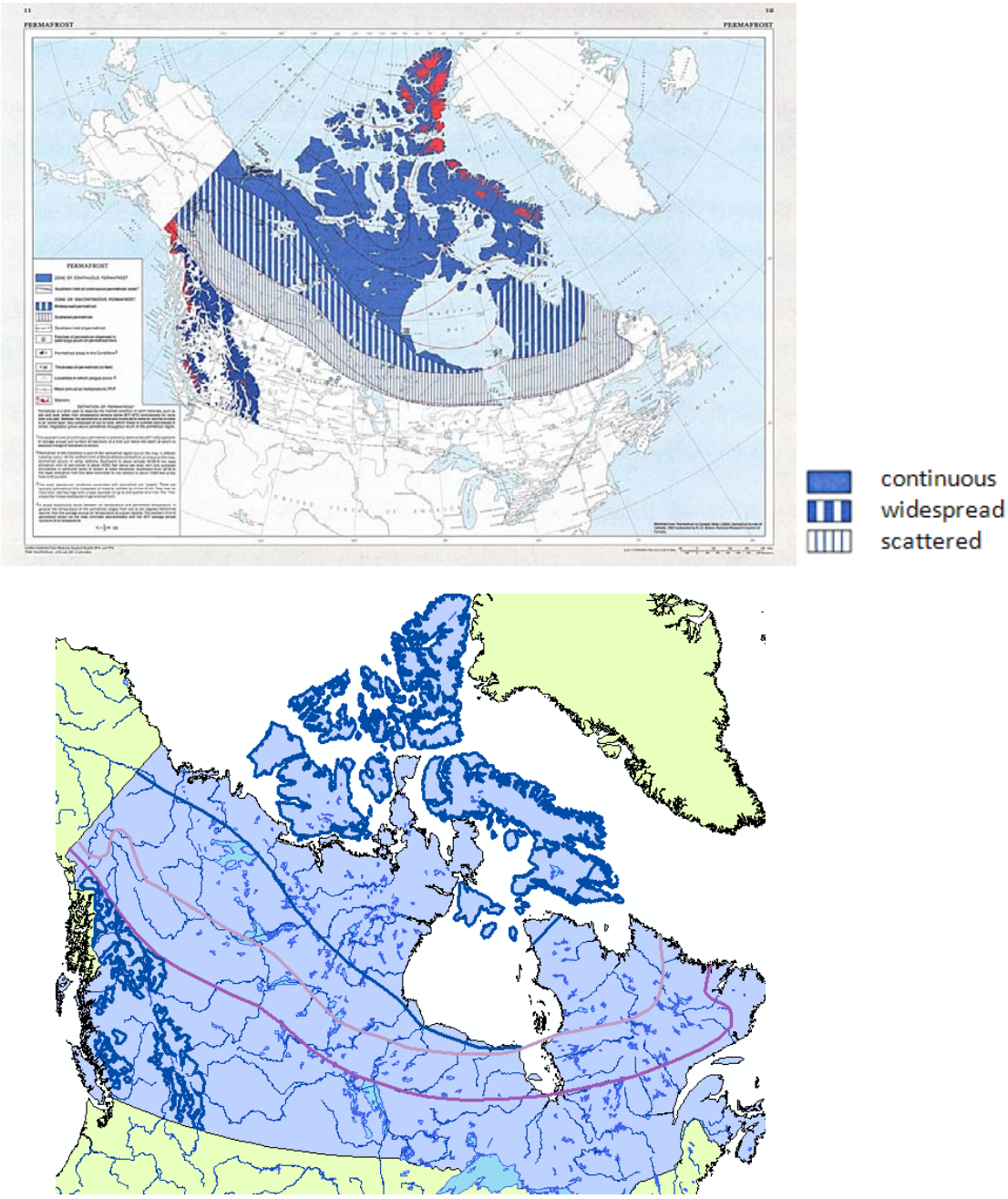

Figure 7: Permafrost map of Canada – the base map and the result of digitizing.

6 Permafrost map of Alaska

Digital permafrost map of Alaska for the years before 80s can be found on the Internet through the link:

http://nsidc.org/data/docs/fgdc/ggd320_map_alaska/index.html

The source map that was digitized had been created by Ferrians, O.J. in 1965, Permafrost map of Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-445. The scale of the map is 1 : 2 500 000.

Permafrost on this map is classified for the following zones**:**

1. Mountainous Area underlain by continuous permafrost
2. Mountainous Area underlain by discontinuous permafrost
3. Mountainous Area underlain by isolated masses of permafrost
4. Lowland and Upland Area underlain by thick permafrost
5. Lowland and Upland Area underlain by moderately thick to thin permafrost
6. Lowland and Upland Area underlain by discontinuous permafrost
7. Lowland and Upland Area underlain by numerous isolated masses of permafrost
8. Lowland and Upland Area underlain by isolated masses of permafrost
9. Lowland and Upland Area generally free of permafrost

The map is presented on Fig. 8. It was digitized using software ArcInfo7 and has a format of an ArcInfo coverage.

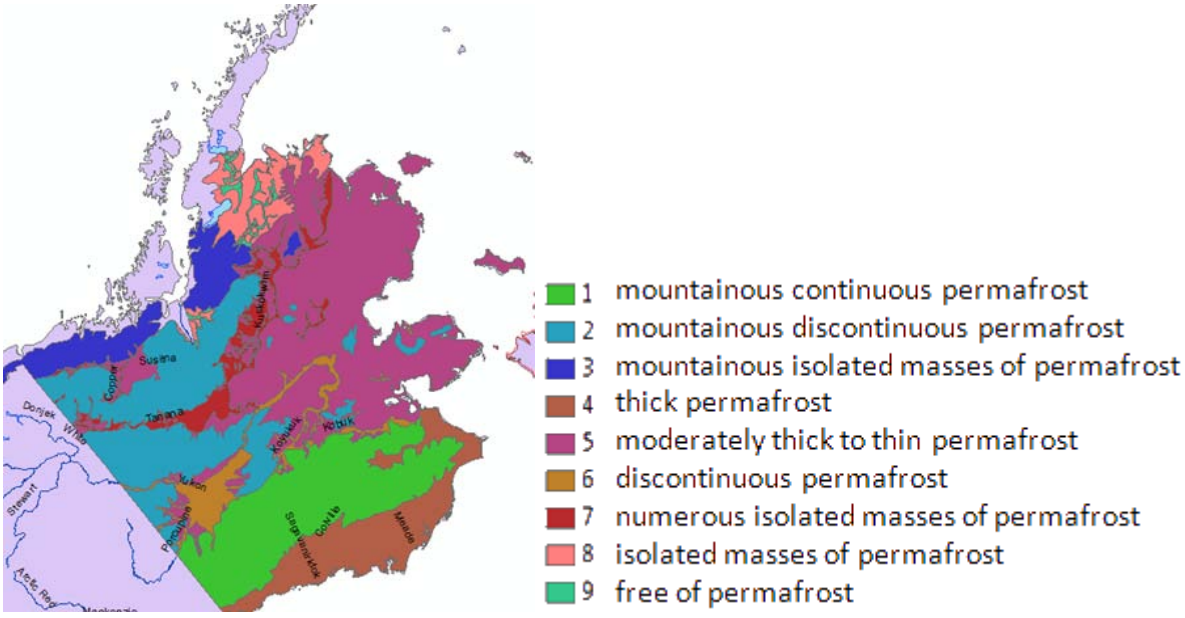

Figure 8: Permafrost map of Alaska.

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