REFINING OF GEOMORPHOLOGICAL MAPS OF YOUNG GLACIAL AREAS BASED ON GEOINFORMATICS AND REMOTE SENSING

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ABSTRACT

Geoinformatics along with remote sensing are widely used as cartography supporting tools that allows revision and digitalization of analogue maps. The aim of this research was to test an applicability of remote sensing data and geoinformatic software in refining and updating analogue geomorphological maps of young glacial areas. The area of research covered glacial areas of north - western Poland caused by Würm glacial period (also called Wisconsin or Vistulian). All analysis were held in ESRI's ArcGIS 10 software. Two types of materials were used: scanned analogue cartographic materials (geomorphological map 1:500 000, geological map 1:200 000, topographic map 1:100000) and digital data (Landsat 5 TM RGB 453 composition and SRTM Digital Terrain Model). During the process a geomorphological map 1:500 000 has been digitalized and rescaled to 1:300 000. All map units has been manually revised, their content updated and borders refined based on information acquired from Landsat 5 TM imagery and SRTM DTM. A coded digital legend has been designed for all of the units. A database with basic geomorphological and spatial information has been attached. The results were: up to date modifiable digital geomorphological map of young glacial areas of Poland 1:300 000 accompanied with database, digital legend of geomorphological units and a printable map layout.

Keywords:geomorphology, mapping, young glacial forms, Landsat, satellite images

INTRODUCTION

Nowadays remote sensing is the main source of up-to-date spatial and environmental information used in map-making, while GIS proved to be highly applicable in its handling (1, 2). Validand detailed cartographic dataare crucial for proper decision making in environmental management, spatial modeling and spatial planning (3, 4). Geomorphological maps can provide information which support such areas as, among many others, disaster and crisis management, landslides analysis or flood prevention (4).In case of Polish geomorphological maps, there is a strong lack of current and small scale cartographic materials (5, 6). For that reasons, there is a strong need for a tool allowing to update the materials in a fast and effective way.

This paper presents an attempt of developing consistent method of analogue map digitalization and revision using geoinformatic software and remotely sensed materials.

STUDY AREA

The area that underwent analysis is north-western part of Poland, a 43538 km^2 in total. From the east the area's border is determined by a 17° 00' E meridian, from the north it is defined by the coast of the Baltic Sea, from the west by Polish - German national border, and from the south by 52° 00' N parallel of latitude (Fig. 1). It is a part of young glacial areas of Poland, caused by the Würm glacial period. Most of the occurring geomorphologic forms are the result of fluvial accumulational, depositional and erosional processes as well as glacial and fluvoglacial erosion and accumulation.

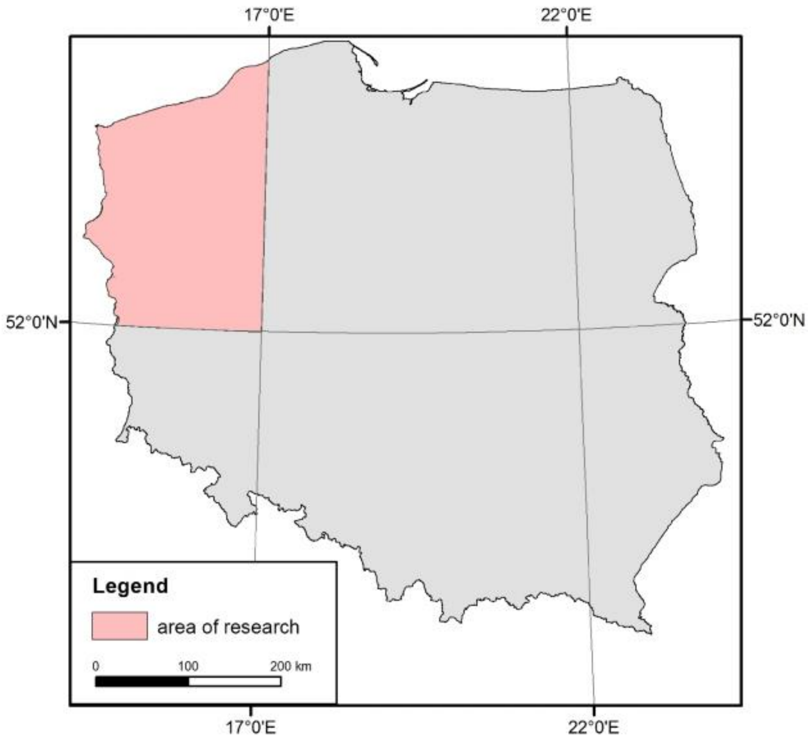

Figure 1: The area of research.

MATERIALS

The main and the most crucial material used in the research was analogue General Geomorfological Map of Poland in 1:500 000 (Fig. 2a) edited by Professor Starkel and designed in 1980 by Department of Geomorphology and Hydrology at Institute of Geography and Spatial organization of Polish Academy of Science (7). It covers 173 land forms, sorted by age, genesis and morphogenetic aspects.

Other analogue materials were: Geological Map of Poland 1:200 000 (Fig. 2b) designed by Polish Geological Institute in 1968-1998 (8) and Topographic Map of Poland 1:100 000 (Fig. 2c), published by General Staff of the Polish Armed Forces, both in SK-42 coordinate system (9).

Main digital material was Landsat 5 Thematic Mapper satellite imagery (Fig. 2d) acquired in June and July of 1992 with a spatial resolution of 30m for visible, near and mid-infrared spectrum, and 120m for thermal infrared.To increase the effectiveness of photointerpretation and strengthen the visual difference between vegetation and other types of land cover, a 453 composition was used (10).

Another material was Digital Terrain Model acquired during Shuttle Radar Topography Mission with scenes of a 1° of longitude and 1° of latitude with a horizontal spatial resolution of 30m and vertical of 90m (10). Due to a small height difference of the area of research, the z value of the DTM had to be increased 10 times in order to enhance the visibility of land forms (6, 14). DTM was used to generate such output as: colored height model, contours for the base map and as a 3D semi-transparent terrain model (5, 6, 14, Fig. 2e).

Figure 2: Examples of used materials.

METHODS

The aim of the research was to digitalize base cartographic material - General Geomorphological Map of Poland 1:500 000 (7) - update its content and change the scale from 1:500 000 to 1:300 000, thus making it more detailed. All analyses described were held in ArcGIS 10.

A following method has been developed during the process (6, 11, 12, 13, 14, Fig. 3):

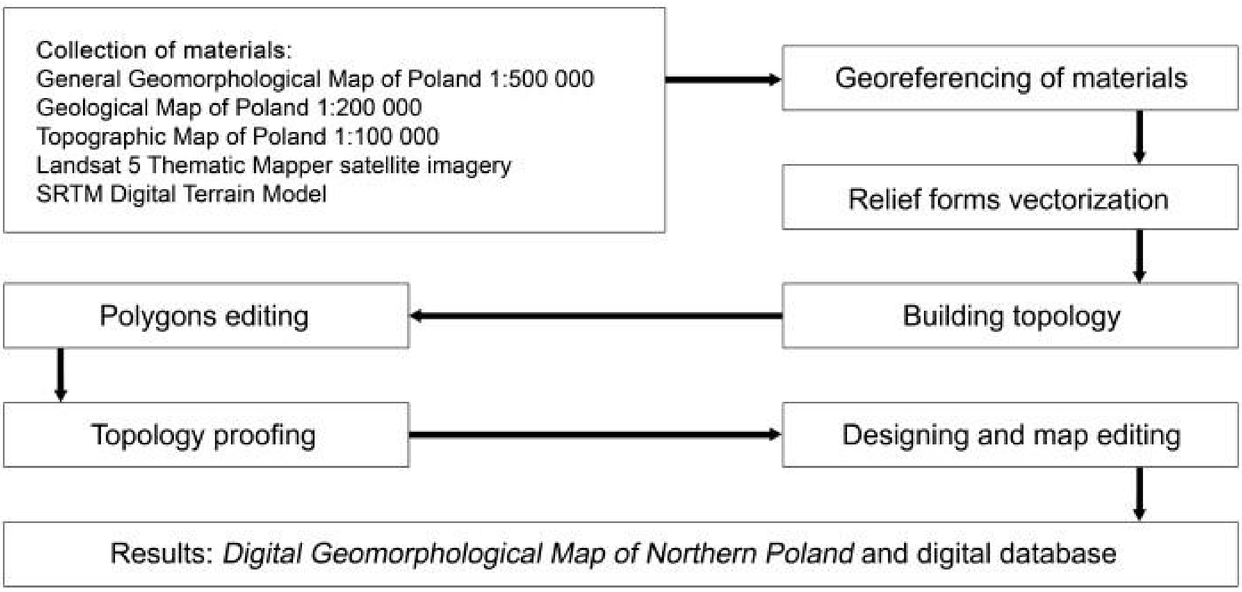

Figure 3: Schemata of the method of refining geomorphological maps.

First step was to collect all materials, both analogue and digital. Next, each sheet of all analogue materials was georeferenced using ArcGIS Georeferencing tool (Fig. 4).The overall RMSE should not exceed more than 1 pixel of an image, which gives an error of 15m in reality. The project was prepared in Polish UWPP 1992 coordinate system (6, 11, 12, 13, 14).

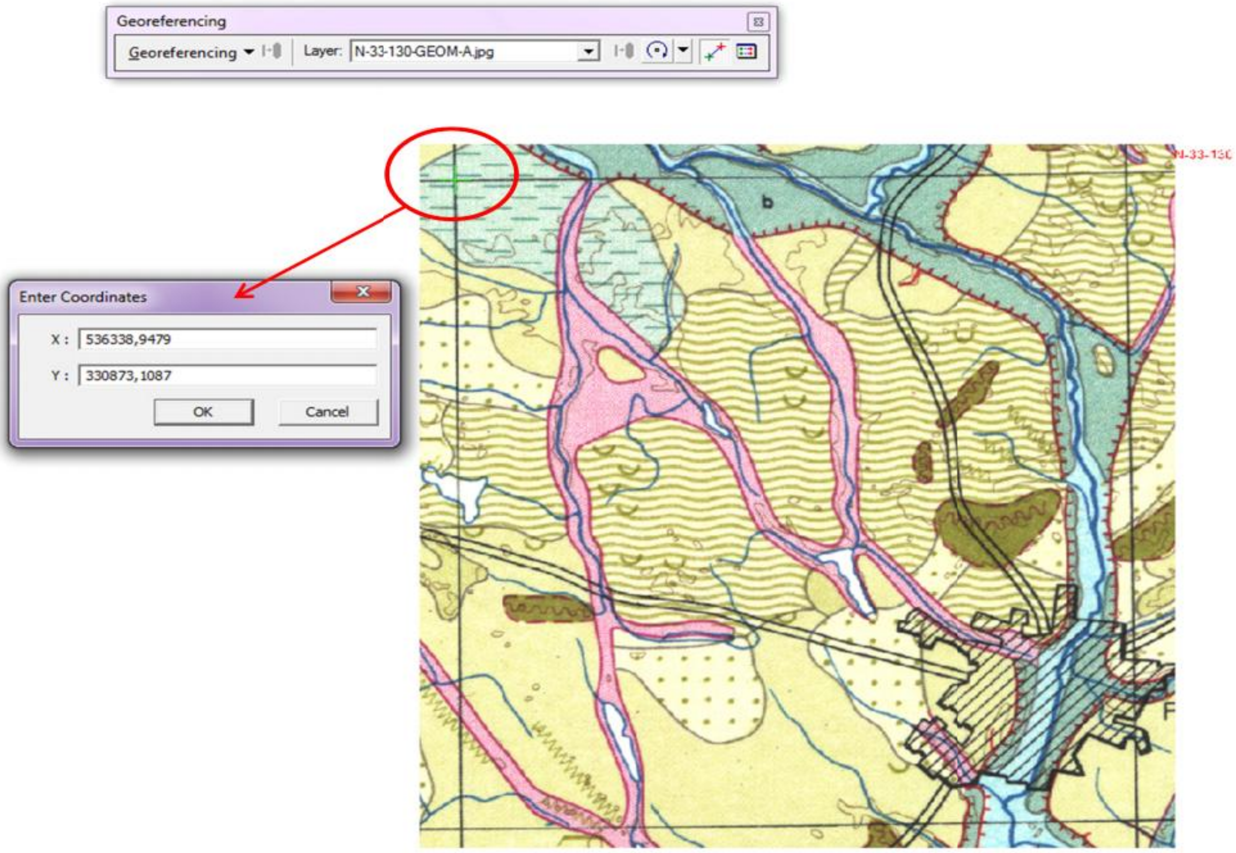

Figure 4: Georeferencing of analogue materials.

Next, all land forms present on geomorphological map of north – western Poland has been selected to be manually digitalized (Fig. 5). Form present on the base material has been consulted with additional sources, from which Landsat 5 TM imagery (10), being the most detailed material, was treated as decisive one. The form was digitalized into polygons (vast terrain forms and surface hydrological elements), polyline (rivers and erosional edges) or marked by a signature (detached, small forms e.g. single kettles) (14).

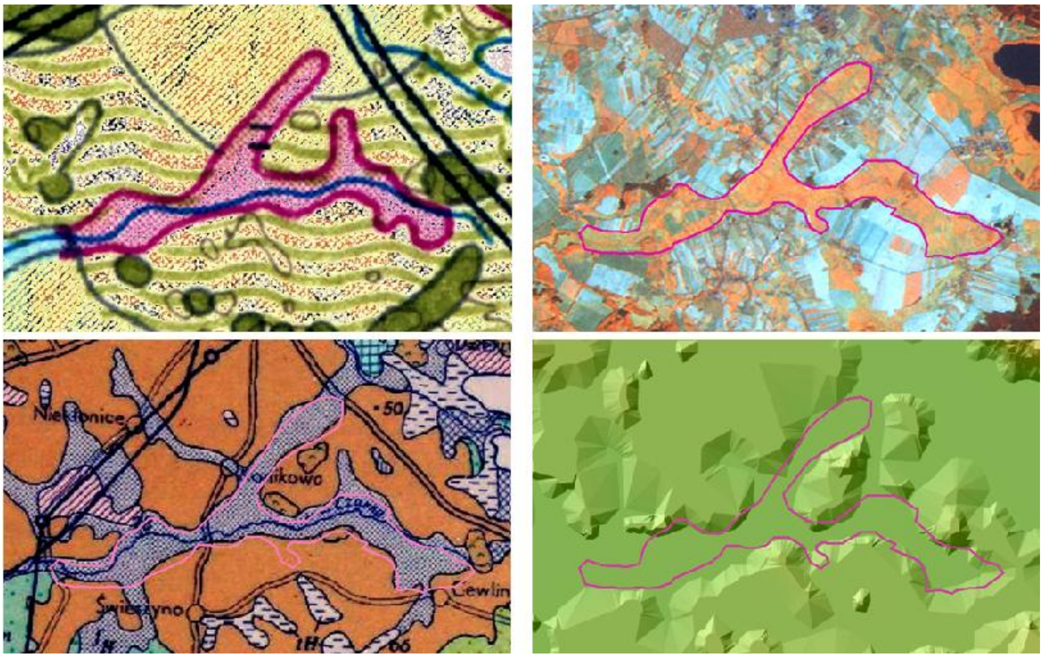

Figure 5: Example of polygon form vectorization: subglacial channels from the Vistulian – form identified on base material has its borders refined through visual interpretation of geological map, Landsat 5 TM image and DTM (14).

The following steps were: topology building and proofing, along with polygons editing. Due to the manual character of the vectorization process, most of the vectorized forms had angular shape.To eliminate this issue ArcGIS PAEK algorithm with a tolerance of 300m was applied (6, 14, Fig. 6). Moreover, a topology check was carried out which eliminated two major errors occurring in case of polygon forms: *must not have gaps* that removed any gaps between two or more forms and *must not overlap* which purpose was to avoid doubling polygons area.

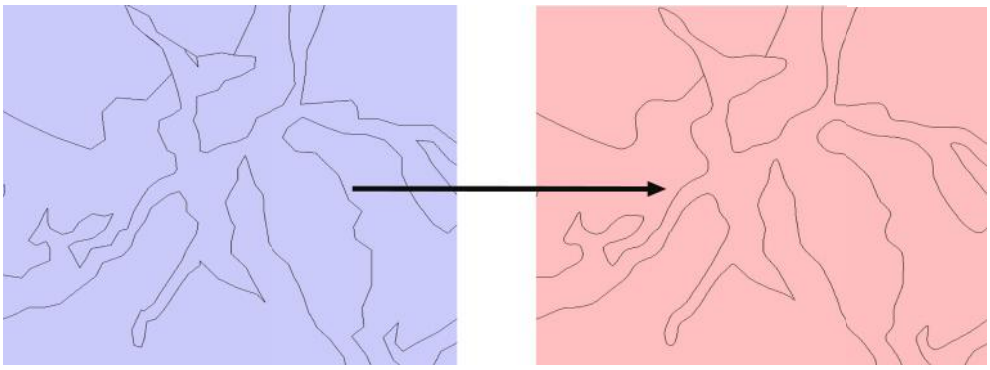

Figure 6: Results of applying PAEK algorithm.

The last step of the process was to prepare a layout of the map. The legend of the General Geomorphological Map of Poland (7) was translated into a digital version, while keeping most of its characteristic, eg. colours, shadings and symbols (6, 11). A hierarchical list of codes corresponding to each form was prepared (6, 14). Codes were added to each digitalized unit in shapefile's table of attributes (Fig. 7) allowing to apply digital legend as .lyr file(6, 14).

Kod *Code*	Symbol *Symbol*	Opis *Description*
42	**Formy erozji rzecznej** *Landforms due to fluvial erosion*	
421	Dna wiekszych dolin płaskodennych *Small Valley floors filled with:*	
4211		Z akumulacją plejstoceńską *Pleistocene sediments*
4212		Z akumulacją holoceńską *Holocene sediments*
423		Wąwozy, wciosy i deberze (w obszarach lessowych i innych) *Ravine and gullies (in the loess areas and other)*
424	Przełomy (w obszarach górskich i wyżynnych) *Water gaps (only in the mountains and uplands)*	
425		Krawędzie erozyjne o wysokości względnej powyżej 20 m *Erosional edges, more than 20 m in height*
426		Inne ważniejsze krawędzie teras (w obszarach rozpoznanych) *Other important terrace edges (in less well known areas)*
428		Koryta rzek (rzeki) *River channels (rivers)*

Attributes of NW_POLAND

FID	Shape *	OBJECTID	CODE	Shape_Leng	Shape_Area
0	Polygon	1	474	5402,245675	721445,194883
1	Polygon	2	474	10322,939031	4059258,06013
2	Polygon	3	474	60225,931041	128540984,304
3	Polygon	4	474	8361,799527	4114069,93122
4	Polygon	5	474	17954,454598	18115358,5243
5	Polygon	6	474	53915,6308	42692819,1341
6	Polygon	7	474	26308,365678	23265066,3569
7	Polygon	8	474	40383,769239	25054282,8245
8	Polygon	9	474	12215,498464	4026497,71119
9	Polygon	10	474	14976,347619	10246202,2221
10	Polygon	11	474	24148,593251	16418669,4377
11	Polygon	12	474	18942,036172	18944382,5245
12	Polygon	13	4701	49934,99463	26429158,5784
13	Polygon	14	477	9136,439201	3182969,35487
14	Polygon	15	477	39883,704416	36391374,4987

Figure 7: Use of hierarchical coding system and attribute table.

Finally, a printable layout of the map was prepared (Fig. 8). It contained the map’s content, legend, graticule, numeric and measured scale, information about the authorship and department (14).

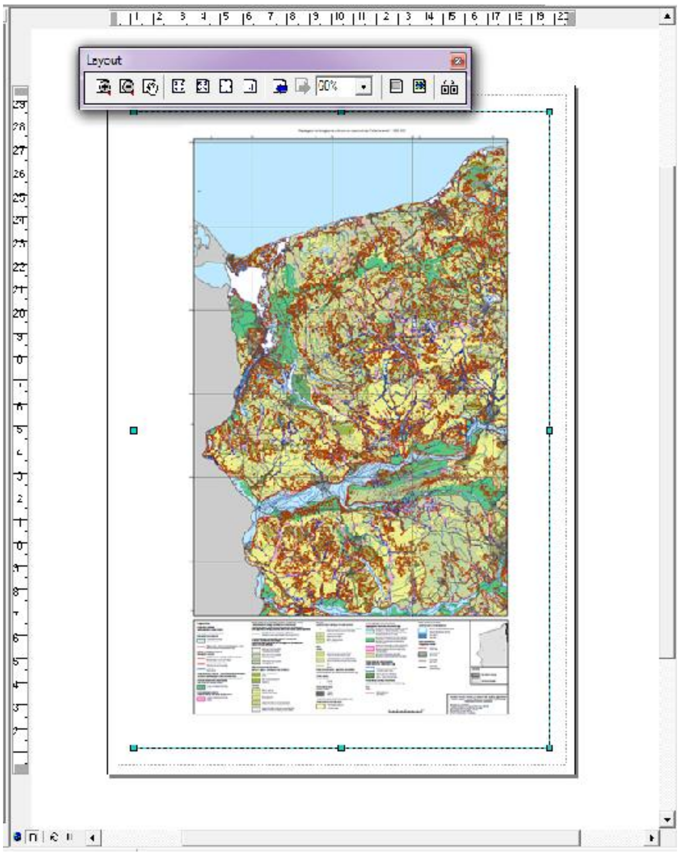

Figure 8: Map's layout.

RESULTS

The result of the conducted analysis is a set of three editable *.shp layers prepared in ArcGIS software containing as follows: 2907 polygons, 1810 polylines and 550 multipoints. A database in a form of table of attributes has been attached to all three shapefiles. The table contains codes of hierarchical numeric legend and basic spatial information about the forms - area or length. The legend consist of 39 types of geomorphological units (27 polygon, 10 polylines and 2 multipoint unit types). Moreover, a printable layout of the map in 1:300 000 was prepared.

CONCLUSIONS

The method presented in this paper shows that remote sensing materials, e.g. Landsat 5 TM (10) are highly applicable in preparation and actualization of geomorphological maps. Moreover, geoinformatic tools have wide application in map digitalization. Though successful, the method proved to be highly time consuming. It can be improved by implementation of automated solutions, thus further studies on the subject are highly recommended.

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REFERENCES

(1) Albertz J, Wiedemann A, 2003.Topographic and thematic mapping from satellite image data, Department for Photogrammetry and Cartography, TU Berlin, www.alwie.net/lit/IstMap.pdf (last date accessed: 20 August 2013)

(2) Pavelka K, 2009.Topographic and thematic mapping from multi-resolution satellite images, Czech Technical University in Prague, Faculty of Civil Engineering, Dept. Mapping and Cartography, Czech Republic, http://www.researchgate.net/publication/228873146_Topographic_and_Thematic_Mapping_from_Multi-Resolution_Satellite_Images (last date accessed:25September2014)

(3) Bocco G, Mendoza M& Velazquez A, 2001. Remote sensing and GIS-based regional geomorphological mapping – a tool for land use planning in developing countries, Geomorphology, 39: 211 - 219

(4) Melelli L, Gregori L, Mancinelli L, 2012. The use of remote sensed data and GIS to produce a digital geomorphological map of a test area in central Italy, In: Remote Sensing of Planet Earth, edited by: YChemin, Italy: 97 - 116

(5) Wolk-Musial E, Gatkowska M, 2011.Detailed geomorphological map of Narwianski National Park with its buffer zone in scale 1: 25000, Polish Remote Sensing of Environment, 45: 40-50

(6) Marcinkowska A, Ochtyra A, Wolk-Musial E, Zagajewski B, 2013.Geomorphological map of pomorskie and warminsko-mazurskie voivodeships using geoinformatic methods, Polish Remote Sensing of Environment, 49: 43-81

(7) Starkel L, 1980. General Geomorphological Map of Poland 1:500 000 (Military Institute of Cartography)

(8) Mojski J E, 1969-1998. Geological Map of Poland 1:200 000 (Polish Geological Institute)

(9) Topographic Map of Poland 1:100 000 (General Staff of the Polish Armed Forces)

(10) U.S. Geological Survey, www.usgs.gov, Web. 10.12.2012

(11) Borzuchowski J, Oledzki J R, 2005.Digital geomorphological map of Karpaty Mts, Polish Remote Sensing of Environment, 46: 52 - 71

(12) Krzeminski J, 2009. General geomorphological map of Podlasie (Poland) in the scale 1:300 000, Polish Remote Sensing of Environment, 42: 43-58

(13) Napiorkowska M, 2011. Digital geomorfological map of Mazovia, Polish Remote Sensing of Environment, 45: 23-39

(14) Orlowska K, Zagajewski B,2013. Digital geomorphological map of north - western Poland in a scale of 1:300 000, M.A. Thesis, Department of Geography and Regional Studies, Warsaw University