GEOGRAFICKÝ
ČASOPIS

57 2005 3

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# GEOMORPHOLOGICAL INFORMATION SYSTEM: IDEA AND OPTIONS FOR PRACTICAL IMPLEMENTATION

**J. Minár, P. Mentlík, K. Jedlička, I. Barka: Geomorphological information system: idea and options for practical implementation. Geografický časopis, 57, 2005, 3, 1 fig., 3 tabs., 41 refs.**

An information system storing relevant geomorphological data and equipped with special analytical tools for geomorphological research can be termed a *Geomorphological information system* (*GmIS*). A GmIS should maintain a comprehensive geomorphological database, allow the user to generate specific geomorphological information and create (carto)graphic, statistical and other outputs. An attempt to create conceptual and logical models of a GmIS is presented here. The proposed GmIS is based on the GIS technology with layered database structure, divided into three main parts. *Adopted layers* imply existing geomorphologically relevant information from non-geomorphological sources. *The basic geomorphological layers* represent the most frequently used immanent geomorphological data: DEM and its derivates, documentation materials, elementary forms, basins, groups of genetic landforms, morphodynamic phenomena and geomorphic network. *The special geomorphological layers* are based on the above and are created by processing them. From many possibilities, two examples of geomorphological and morphostructural analysis are outlined. ESRI ArcGIS is suggested as the management system for geomorphological data.

**Key words:** geomorphology, GIS, mapping, geomorphological information system, geodatabase

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# INTRODUCTION

The Geographical Information System (GIS) is an excellent tool for the collection, elaboration and presentation of geo-space data used in various geosciences. The cartographical database and analytical-modelling aspects of GIS are distinguished (e.g. Koreň 1995, Longley et al. 2001) and each of them can be specifically used in single cases. Object properties and purpose provide a base. If we define the landform as the object and comprehensive geomorphological research as the purpose of GIS building, the *geomorphological information system* (*GmIS*) can be postulated as a specific a type of GIS. Creation and use of specific symbols and legend in geomorphological maps (e.g. Kusendová 2000, Létal 2005) is the example of cartographical specification of GmIS. GIS – supported methods of geomorphic data collection (e.g. Voženílek and Sedlák 2001, Mentlík 2002b) and mainly the creation of specific geomorphological database (e.g. Barsch and Dikau 1989, Dikau 1992, Minár and Kusendová 1995) represent specific database aspects of the GmIS. The widespread Digital Elevation Model (DEM) and its derivatives can be an example of specific analytical-modelling aspect of GmIS.

All the above-mentioned examples only deal with the problem of GmIS creation in part. The problem should be resolved in connection with development of general geomorphological theory and methodology as well as in practise requisites. We attempt to outline the conception and structure of the core of GmIS that is focused on complex description and research of a geomorphic region in detail, followed by relevant experiences (Dikau 1992, Minár and Kusendová 1995, Schmidt and Dikau 1999, Dehn et al. 2001, Beták 2002, Mentlík 2002a, Bonk 2002, Jedlička and Mentlík 2003, Skurková 2003). The emphasis is on the realization conditions (methodology and dataset specifics) in Slovakia and the Czech Republic.

The use of GIS in geomorphological research and mapping brings an important qualitative shift. It reinforces objectivity, makes a wider verification/falsification frame. And it also gives the new possibility of more exact analysis and synthesis. Moreover GIS technology makes possible a more effective utilization of results of geomorphological research in geoecology, geology and environmental applications. It is a definite world trend, which should be developed and supported systematically.

A GmIS should deal with the specific problems of collection of landform-specific information, their effective storage, revision and complement the elaboration and creation of new (synthetic) geomorphological information as well as visualization of outputs. The flexible structure of the original geomorphic database plays the key role here. Sufficient tools of data adaptation, elaboration and visualization should accompany it. A GmIS has to be able to import and unify coordinates of analogue map materials of various provenances, data from GPS supported field research, remote sensing and various sources of DEM. Visualization includes mainly the creation of analytical and synthetic geomorphological maps as well as 3-D or 4-D (time simulation) images of landform properties. But we target the problems of geodatabase structure and its construction, which include the elaboration of primary information and the generation of new geomorphic information.

We suggest the layer structure of geodatabase similar to the pioneering approach GMK 25 (see e.g. Barsch and Liedke 1985, Barsch and Dikau 1989), however, the functional basis is a priority. Generally we consider the *adopted layers* (primary non-geomorphological), *basic geomorphological layers* and *special geomorphological layers*.

## ADOPTED LAYERS IN THE GMIS

Adopted layers are the most important existing spatial source of geomorphologically relevant information that was created for another purpose. They are used for creation of basic and special geomorphological layers. The following are the most frequently used adopted layers.

*Topographic maps* are the most often used base maps for geomorphological mapping. The preferred maps for detailed mapping are on scales of 1:10 000 or 1:25 000; with a contour interval ranging from 1 to 10 m. The advantages of topographic maps are contiguous coverage and accessibility, but low accuracy and a high level of generalization are sometimes a problem. The accuracy can vary between the map sheets depending on the cartographer. Contours, vectorized from topographic maps, are frequently used as the input data for interpolation of digital elevation models (DEM). Topographic maps are now also available in digital form (raster or vector), therefore the incorporation of them into a GmIS can be very easy. Different types of objects should be saved in separate layers (contours, roads, etc.)[1].

*Orthophotomaps* offer very accurate information on the location of certain geomorphic objects and their boundaries, if they are sharp enough. The effects of recent geomorphological processes are also visible on orthophotomaps, but this applies only to open landscape, without higher vegetation. Geomorphological features can hardly be seen in forest and shadowy areas in the mountains. Orthophotomaps should be preferably created from aerial photos taken during spring or autumn, because of the lack of vegetation. A chronological sequence of orthophotomaps, can bring remarkable results in morphodynamic research. Aerial photos from the 1940s to the present are usually available in Central Europe regions, but orthophotomaps with high resolution are less accessible for the present.

*River network* is an important layer that can be adapted from special hydrological maps, topographical maps or orthophotomaps. It is a useful input for basin layer construction forasmuch as it represents the network of main valley lines (thalwegs) – boundaries of half-basins and confluence points are starting points for watershed delimitation. Valley lines are also either boundaries of elementary form or centre-lines of specific elementary forms. River networks are very effectively used in the creation of geomorphological network and morphostructural analysis. Automated methods of valley line network generation are now a part of more standard GIS technologies. If necessary, the other hydrological layers can be added (springs, water areas, marshes).

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[1] For example a fundamental database of geographical data such as ZABAGED or DMÚ is available in the Czech Republic.

*Geological data* is very important for geomorphological research. Obviously the quality of the data is closely connected with the state of geological research of the area. Geological maps on a scale of 1:50 000 exist for the whole of the Czech Republic and a major part of the Slovak Republic. We can get these maps in the Czech Republic in digital (vector) form. It is possible to get geological maps in a more detailed scale for selected areas. The structure of adopted geological information and its function within GmIS is shown in Tab. 1.

**Tab. 1. Geological information in the geomorphological information system**

| Layer specification | Layer characterisation | Layer function |
|---|---|---|
| Type of bedrock (lithology) | Polygonal layer | General information about extent of particular types of rock. |
| Geological boundaries (between types of bedrocks) | Polyline layer (position and specification of the boundaries). | Used in morphostructural analysis – mainly if the geological boundaries correlate with geomorphological lines. |
| Faults (different types of faults) | Polyline layer (position and specification of the fault). | Information about tectonic conditions. Used especially in morphostructural analysis. |
| Pits and boreholes | Point layer (position and description of rocks). | The most reliable and detailed lithological information. |
| Geological profiles | Polyline layer (position and stratigraphic character). | One-dimensional extrapolation of subsurface extent of rock types. |

*Soil maps* could also be an important source of information, especially when quaternary morphodynamic research is done. Soil type, class, depth, skeleton content and subsoil type are usually available in maps on scales of 1:5 000 (agricultural areas) – 1:50 000, but the accuracy of soil maps is often insufficient from a geomorphological point of view.

Some other kinds of sources are also usable in geomorphological research, including *historical maps* (e.g. if the rill erosion is studied), *land use* or *land cover maps* (morphodynamic research), *triangulation and leveling nets* etc. These can also be incorporated as individual adapted layers into the GmIS.

## BASIC GEOMORPHOLOGICAL LAYERS

Basic geomorphological layers are fully or partially independent structures of basic geomorphological information. They represent the most frequently used information and should be a fundamental part of GmIS. We can define seven basic groups of layers. Each group has a particular position and function within the system (Tab. 2).

*Digital elevation model* (DEM) is one of the most frequently used inputs in the spatial analysis and usually a crucial tool in modern geomorphological research. The DEM serves as an input for *derivation of morphometric indices*, such as slope, aspect and curvatures, in the process of *finding features on the* *terrain* (drainage basins and networks, elementary forms, etc.) and *modelling* of hydrological functions, energy flux, forest fires and so on. The term DEM can be used to refer to any digital representation of georelief (thus also to vectorized contours and regular or irregular field of points). But more often it means a raster (or regular grid) of spot heights, or so called TIN – triangulated irregular network. Both raster and TIN representation have their own advantages (cf. Tuček 1998).

**Tab. 2. Position and function of basic geomorphological layers in GmIS**

| Name | Generation | Function |
|---|---|---|
| DEM and its derivatives | Generated from adopted layers (topographic maps, orthophotomaps, geodetic nets and river networks) by mathematical modelling. | Generation of other features (elementary forms, basins, geomorphic network) and computation of their morphometric characteristics. |
| Elementary forms | Defined morphometrically on the basis of DEM and verified and modified by geomorphological (GPS) mapping. | Basic part of a GmIS. Other features just provide extra information for them. Extrapolation of genetic, chronological and dynamic properties and geomorphological regionalization. |
| Basins | Derived from DEM (with use of river network layer) and verified by geomorphological mapping. | Basic actual morphosystems. Modelling of actual processes. Boundaries provide information about each form, which they intersect. |
| Documentation materials | Received by geomorphological (GPS) mapping or from the adopted layers. | Connection of morphogenetically relevant information with other features stored. |
| Morphodynamic phenomena | Received by stationary research and field mapping as well as from adopted layers. | Connection of morphodynamically relevant information with other features stored. |
| Geomorphic network | Derived from DEM and orientation of geomorphological features. | Used mainly for morphostructural analysis and general genetic interpretations. |
| Genetic groups of landforms | They connect parts of georelief according to their genesis. Derived from elementary forms and field survey using adopted layers and morphodynamic phenomena. | Thanks to the genetic groups of geomorphological forms it is possible to create special maps of genetic forms of the area of interest and other specific layers. |

The DEM can be constructed from several kinds of input (source) data. A common way is to interpolate the DEM from the points extracted from vectorized contours, sometimes supplemented by special points (peaks, saddles, etc.). Photogrammetry offers another possibility of obtaining the input points, which can be done manually or automatically. LIDAR[2] aerial scanning is a modern method capable of producing very accurate digital representations of the surface. Additional precise geodetic and GPS mapping of elevations are needed to cover fine topographic features (gullies, terraced slopes, etc.), especially when working in large map scales.

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[2] Technology of using pulses of laser light striking the surfaces of the earth and measuring the time of pulse return.

There are many possible interpolation techniques used for creating the DEM, and available software packages differ in their number and modes of utilization. The user should be familiar with the properties and behaviour of a chosen interpolation function to acquire the best results. Frequently used methods can be divided into several classes: polynomial trend surfaces, Fourier analysis, local surface estimators, splines and geostatistical functions (Burrough and McDonnell 1998, Bonk 2003). The accuracy of interpolated surface depends on several factors: accuracy, density and distribution of the source data, the characteristics of the terrain itself, the method used for the creation of the DEM and the characteristics of the DEM surface which is constructed from the source data (Li 1990). The characteristics of the resulting DEM have to fulfill its purpose, for example, a DEM for hydrological modelling should be smoothed and without artificial depressions, but a model for edge detecting should not. Morphometric characters can be computed from the existing DEM or together with computation of the DEM (e.g. if using splines). The accuracy of derived characters highly depends on characteristics of the DEM.

Integration of the DEM and morphometric data into a GmIS is preferably in the form of raster layers, but TIN representation can be useful from the point of view of accuracy (cf. Krcho 2001). Sometimes the creation of a special DEM is needed, therefore GmIS may contain several different DEMs of the same area, or source data (spot heights), which provide the possibility to derive them. Therefore the layer of input points seems to be an important part of the GmIS. A series of surface profiles can be generated from the DEM and stored within GmIS to analyse georelief better. Cross section profiles can be generated from either XY coordinate pairs, or from an existing line layer (e.g. valley lines).

*Elementary forms* represent the basic (geometrically, genetically and dynamically homogeneous) parts of landform (Minár 1992 and 1998). They are defined by a constant value of some significant morphometric characters (altitude and its derivatives) and some lines of discontinuity of these characters bind them. Constant value of morphometric characters is connected with any kind of genetic, chronological and dynamic homogeneity and discontinuities represent natural boundaries of landforms, where this homogeneity is corrupted. Therefore morphometrically defined elementary forms can be extrapolation base of genetic, chronological, dynamic and lithological information too (stored in various point and linear layers of the GmIS) and create a base for complex geomorphological maps (see e.g. Minár and Mičian 2002) and evaluation of natural hazards and risks (Minár and Tremboš 1994). Marked discontinuities can be interpreted as lines of the geomorphic network.

Visual identification of elementary forms is a traditional way of landform elementarization (e.g. Beručašvili and Žučkova 1997, Urbánek 1997). However, the exact geometrical definition of elementary forms (Minár 1998) and thus possibilities for automation of their delimitation are fundamental for their utilization as a basic layer of GmIS. Objectification of elementary form delimitation creates a more scientific basis for geomorphological mapping. However, implementation of definition equations of elementary forms for their automatic identification and characterization has not yet been solved. We work out the algorithm using morphometric analysis, which should be implemented in the GmIS. The problem is that the elementary forms concept considers a contrast model of georelief, while morphometric analysis starts from the precondition of continuity (without any discontinuities), which we can call the smooth model. However, discontinuities from the contrast model should be identical with zero isolines of second derivation of the discrete character in the smooth model (altitude discontinuity and zero isoline of profile curvature, slope discontinuity and zero isoline of change of profile curvature and so on). The precision of computation of the morphometric characters of a higher order is the biggest problem here. The computation of definition constants of form-defining equations of delimited elementary forms is more an easier case. The mean values of form-defining morphometric characters (characters with constant value) can be a base. However automation of elementary forms delimitation requires the creation of a new, original geoinformatic solution.

*Basins* (*watersheds)* are natural hydro-geomorphological units, which reflect the spatial organization of the most important exogenic geomorphological processes. The watersheds delimited represent natural segments of the surface of the Earth, different as elementary forms. These segments of the georelief are linked by dynamics of current geomorphological processes, mainly in Central Europe, where the fluvial processes are the most powerful geomorphological factor. They are frequently used as basic operational units in various hydrological and geomorphological analyses. The basic units are presented as elementary basins (catchments) or they divided in more detail into half-basins (divided by valley lines) and inter-basins (the parts of basins of a higher order that are not part of any basins of a lower order). Elementary forms usually split the basins in more detail, however the boundary of basins can divide the elementary forms too (when the basin boundary is a regular flowline). Basin and half-basin boundaries (watershed-lines and valley lines) have an important position in geomorphological research. Firstly, these lines provide information on geomorphological processes running along the lines and also in their vicinity (the energy of geomorphological processes is dispersed in the vicinity of ridgelines and concentrated along valley lines). We can combine the information about the character of the geomorphological processes with the particular elementary forms (or other geomorphological forms), which are intersected by these lines. Secondly, the pattern of these lines supplies initial information on the spatial configuration of the georelief and can be used for geomorphic network generation.

Morphometric characterization of basins is very important. Techniques such as hypsometric analysis (Strahler 1952) are widely used, particularly for analysis of morphostructural conditions (Jamieson et al. 2003, Pánek 2004 etc.). For this analysis we usually use characteristics, which are derived from DEM. These characteristics can be divided into two groups: characteristics of a basin-wide nature (hypsometric integral, relief ratio, elongation ratio etc.) and characteristics of drainage network (drainage density, bifurcation ratios, stream frequency etc.) (Jamieson et al. 2003). It could be a basic ability of GmIS to derive and manage these characteristics. But it is necessary to provide specific tools, because they are usually not a part of common GIS products.

We can delimit the basin boundaries using GIS tools. Although the grid of the watershed is a result of the GIS operations, we usually create a vector layer from the result, because we ordinarily use the vector theme for further analysis.

Watershed boundaries are also a part of ZABAGED in the Czech Republic (as an individual layer).

*Documentation materials* represent a compound information layer of punctual or linear information about outcrops and soils but also landform, vegetation and hydrological features. The core of the layer creates data collected during the field geomorphological research, but data from existing boreholes, pits or profiles can be added. The concept of documentation points is widely used in the geomorphological mapping (Demek et al. 1972). Certainly, this concept has been appended in the area of the geomorphological information system.

A lot of exposures (natural or artificial) including small forms (gullies, scarps, meander-cut banks, road/rail cuttings, quarries, sand pits and so on) are recorded on a map of the documentation points during geomorphological mapping. However, some are represented by lines (depending on the map scale). For all these points and lines we should record a clearly defined description. A basic description of the exposure includes (Demek et al. 1972. p. 115):

1. situation,
2. dimension: height, width,
3. type of exposure: natural or artificial,
4. description of one or more characteristic profiles in the exposure, lithological data, granulometric composition, stratification, special phenomena etc.,
5. stratigraphic classification,
6. genetic interpretation of the exposure, its relation to surface forms and the general relief.

Demonstration of recent geomorphic processes on soil, relief, vegetation and hydrological features should be added systematically. Some of this information is entered into the GmIS directly (e.g. position recorded by GPS). We can record other information in a geodatabase, prepared before mapping (see Voženílek et al. 2001).

Documentation points and lines provide morphogenetically, morphochronologically and morphodynamically relevant information. Using spatial relations (intersect etc.) we can combine this information with particular elementary forms, compounded forms or basins. This systematically increases the information content of each form.

*Morphodynamic phenomena* – actual geomorphic processes are not only shaping georelief, but some of them can pose a hazard to human society and therefore they should be incorporated into GmIS. Firstly, data related to morphodynamics and collected during field research are stored in documentation materials layer. Periodicity, intensity and other relevant characteristics should be stored in the attribute table. As the next step, they should be extrapolated to the area of interest with some help from morphometrical, geological and land-use features of the basic and adopted layers (e.g. a limestone area determines the spread of karst dissolution – cf. Stankoviansky 1988). As such extrapolation in detailed scale is almost always a serious scientific problem, morphodynamic phenomena can be added as the attributes to the layers of potentially dynamically homogeneous elementary forms or basins.

The materials collected by stationary research methods at field stations bring precise information on the intensity and frequency of geomorphological processes. Although stationary research is time consuming, the localization of such field stations in a study area greatly improves the precision of morphodynamic data. Data of permanent observation stations, selected primary morphodynamic information from documentation materials and polygonal layers of extent of morphodynamic phenomena create layers of morphodynamic phenomena.

*A geomorphic network* is created by visualization of linear elements of georelief (various discontinuities such as valley lines, foothill lines or scarps) to create regular network. Visual analysis of topographical maps or orthophotomaps is the most widely used method of geomorphic network creation (e.g. Urbánek 2004), but attempts to objectify of the process exist (Jedlička and Mentlík 2003). GmIS is an ideal tool for this. The boundaries elementary forms (various discontinuities) and half-basins (valley lines and ridge lines) can be systematically investigated from the point of view of their basic geometrical quality (convex and concave boundaries), sharpness (difference of morphometric characters of areas divided by boundaries), bulkiness (area of the separated forms of the highest order) length of the line and their straightness. Standardized weight can be assigned to the separate characters and preferred directions or shapes can be determined by statistical analysis. A statement of decision algorithm contains of course subjective aspects, but statistical evaluation ensures homogeneity of evaluation in space and objective comparison of various regions is possible.

Adaptation of the algorithm outlined represents one of the specific tools of the GmIS, which differentiates the GmIS from other GIS. However, traditionally made geomorphological patterns can be incorporated into the GmIS too, and can be verified by comparison with elementary form and basin datasets at any time later.

*Genetic groups of landforms* create specific cross-sectional geomorphological layers integrating selected elementary forms, basins, documentation points and lines, but also other elements on the basis of genesis. Distinguishing a specific genesis of all elementary forms we can use layers of genetic groups of elementary forms to create special morphogenetic maps (for example a map of glacial, fluvial or cryogenetic forms). But some important genetic forms can be too small for areal representation (e.g. small kryoplanation terraces, frost scarps, spring kettles in the case of cryogenetic forms) and so they are expressed on a map only by a point or line. This can occur with a lot of forms recorded in layers of documentation points and lines. On the other side the autonomous genetic interpretation of some elementary forms can be a problem and they can be jointed into genetically homogeneous compounded forms (e.g. moraines compounded from some geometrically homogeneous segments). Creation of particular geomorphological maps of individual groups of genetic forms (involving all the mentioned cases of representation) can be very useful during geomorphological analysis. The composition of this part of the GmIS depends on the approach and area of interest and so it is not possible to describe all thematic layers directly.

## BUILDING OF SPECIAL GEOMORPHOLOGICAL LAYERS

Processing basic geomorphological and adopted layers can create a number of special geomorphological layers. They can develop the basic geomorphological research (comprehensive basic gemorphological analysis) or be centred on an application (geomorphological hazards and risk evaluation, landform potential for some activities and so on). We outline only some aspects of special geomorphological layers creation as examples.

Geomorphological analysis is directed towards understanding the genesis and evolution of landforms. *The traditional geomorphological map* represents the most common output from such an analysis. We offer an algorithm describing geomorphological analysis by combining more approaches (Demek et al. 1972, Minár 1995, Urbánek 2000, Minár and Mičian 2002):

1. Definition of the area under concern and preparing of basic geomorphological layers.

2. Delimitation of complex mapping units (elementary forms, compounded forms, types of georelief) according to their genesis. Layers of the elementary forms and genetic group of landforms are used and made up in this step.

3. Overlay of complex mapping units and genetically relevant layers (mainly documentation points, but also geomorphic network or selected adapted layers) and assignment of the genetic information to particular mapping units.

4. Characterization of boundaries of mapping units from a genetic point of view.

5. Identification of geomorphosystems, creation of a local/regional morphogenetic hypothesis and subsequent completion of genetic interpretation of all mapping units.

6. Hierarchical, morphogenetically oriented regionalization in harmony with local/regional morphogenetic hypotheses and its map presentation.

The resulting geomorphological maps then present a visualization of the geomorphological analysis stored in a specific layer of the GmIS.

The modern *complex geomorphological maps* (Minár 1995) are an specific case of the traditional geomorphological maps. They are based on depiction of morphometrically, genetically, chronologically and dynamically characterized elementary forms. The ambition to express all fundamental geomorphic characters in one map is limited by the ability to express them sufficiently legibly. Therefore the code representation of all relevant information (Minár 1995) is substituted by a preferred image of genesis and age (similar to traditional geomorphological maps – e.g. Minár and Mičian 2002, Beták 2002, Skurková 2003), but distinguished on such a level, which ensures the morphometrical and dynamical homogeneity of elementary areas (forms) too. Indirectly assigned genetic and age characteristics of elementary forms have to be systematically confronted with directly assigned relevant morphometric characters of elementary forms as well as with other components of the geodatabase (documentation materials, geomorphic network, adapted layers). GmIS can provide this by a system of queries and tests.

The specific important role of the GmIS consists of the process of hierarchical geomorphological regionalization. The GIS environment supports the methods of regional taxonomy (multivariate statistical methods) that can bring more objective results than traditional approaches or they can be an important part of it.

The fundamental role of a complex geomorphological map is the summarized expression of regional geomorphological theory created by synthesis of local theories (explanations of the origin of simple elementary or compound forms and basic geomorphosystems). As a rule, more synthetic explanations of the system of local theories exist. These hypotheses should be verified (falsified) by a set of experiments (verification of hypothesis of lower order), which can be effectively carried out in GmIS. GmIS also enables systematic revision and actualization of maps as well as effective creation of graphic aspect of complex geomorphological maps.

*Morphostructural analysis* is a specific way of explaining direct and indirect links between geological conditions and the landform of the area of interest. It is a complex system of methodical approaches, which we can divide into two main groups – geomorphological and other (nongeomorphological) methods (Lacika 1986). The most important problem of morphostructural analysis is that we cannot repeat all the stages of the analysis and confirm or negate the results. The problem is obvious – a lot of parts of these processes are based merely on the empirical suggestions of the researcher. However, we have a good opportunity to revise the older methods and rebuild them on a more exact base in the GIS environment. The GIS provides good tools for some traditional steps of morphostructural analysis such as analysis of longitudinal and cross-section profiles of valleys, analysis of types of geomorphic network (river network), analysis of planation surfaces and river terraces, etc. We can also be engaged in the analysis of geological information in a geomorphological context. Analysis of strata fault and fracture characters and their connection with georelief could be an example.

We should postulate special procedures, which would provide some steps of morphostructural analysis semi-automatically or automatically. We have already made some suggestions regarding morphostructural analysis in GIS (Jedlička and Mentlik 2003). The example deals with analysing geomorphological lines, which seems to be a useful part of geomorphological research, especially, in areas where passive morphostructure predominates.

## OPTIONS OF PRACTICAL IMPLEMENTATION

The GmIS has the same functionality as the classical geospatial information system (see e.g. Longley 2001). This section describes how GIS functionality can be exploited for GmIS. We understand GmIS to be a special type of GIS, which focuses on geomorphology. It is obvious that GmIS can exploit all the functionality of classical GIS (in data store, data analysis and data visualization). This means that the GmIS should be able to maintain a complex geomorphological database, allow the user to generate specific geomorphological information and create (carto)graphic, statistical, and other outputs from that spatial database.

*Geodatatabase* (also called geographical or (geo)spatial database) is just a special type of database, but most of the process of building it comes from classical database design[3]. The main difference between a classical and a geographical database is that a geodatabase stores spatial data.

We have selected the database format for storing and maintaining the GmIS, because of its ability to handle and store data safely, and work with a huge amount of data. We have chosen a spatial database because of its fast handling capability of spatial data using spatial indexes. And finally, we have suggested the ESRI Geodatabase for all of the above reasons, because of its topologies[4] and because it is widely used.

The database structure (not only ESRI Geodatabase) also has an advantage in simple data import and export. The ESRI Geodatabase has the advantage that you can export data to shapefiles (and also to the many other formats), which is the "de facto" standard format for geodata exchange in the GIS community.

*The geomorphological database* is the core of the GmIS, so it has to be developed in a really robust way. The development has been based on the synthesis of more geomorphological methodologies (Demek et al. 1972, Minár 1995, Urbánek 2000). We are building a conceptual, logical and physical model of the geodatabase, following the classical database methodology.

The c*onceptual model* is mainly about getting the user's points of view, which are usually gathered from all potential database users (Dobešová 2004). It should show logical groups of features, which we can understand as the initial structure of the future feature layers and groups of those layers in the following logical and physical model. The conceptual model also shows dependencies among these layers and layer groups. The database designer then builds a *logical model* by specifying the conceptual model. It is important to determine the way of the representation of the real feature layers. It means choosing a point, line, polygon or other representation for spatial data and the relevant attribute type (number, string, etc.) for attribute data in those layers. There are also more formalized dependencies among its elements (as relations, topologies and sometimes functional dependencies). The logical structure of the GmIS with its functional dependencies is sketched in Fig. 1.

There are also other types of relationships among layers or groups of layers in the logical model, which are not sketched in the diagram. One type is topology. Topology means that there is a spatial relationship between two feature layers. It is useful to maintain topologies, because they are similar to relations and domains in a classical database – they maintain the spatial integrity between spatially related layers in the geodatabase. Relationships are common in classical databases so we do not discuss them here (see e.g. Arctur 2004, Dobešová 2004).

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[3] We use the term "database" or "geodatabase" below. This means that it is the same structure, but we want to outline a methodology, which comes from classical database design, when we use the term "database" instead of the term "geodatabase".

[4] Using topologies can save about one third (depending on the particular structure) of relations between tables in a database. It simplifies the database structure and also speeds up the database (ESRI 2005).

The logical model has to have a compact well-defined core, which is the basis for the physical model. In our point of view, this is a fixed division into logical groups of layers. The logical structure of the GmIS should also stay open, because it is going to be used at different places of interest and by different geomorphological schools. It is possible to fill it with other layers which are not in the proposed structure, or not to use all of the layers from the structure. That decision can be made based on the particular area of interest. Nevertheless, the division into groups should stay fixed.

The *Physical model* is the real database stored in a database management system (DBMS)[5]. It is not the object of the article to describe the physical model, but it is necessary to create all of these models during the development of the database structure, because it is an iterative process. This means that until you have the final physical model you can still expect changes in both the conceptual and the logical model.

*Generation of specific geomorphological information* is a crucial function of the GmIS. The tools for geospatial data analysis are generally a very important part of GIS (see e.g. Burrough and McDonnell 1998, Longley 2001). It is very important to have a well-developed geodatabase structure to exploit all of the GIS analysis functionality. We can use many common programming, scripting or graphical languages to create complex analysis models. These analysis models can combine standard GIS tools and specific geomorphological tools (which can be developed by the GmIS creator). These models together create a "Geomorphological Toolbox", which will be used to gather specific geomorphological information or to create specific geomorphological outputs. They correspond to the attribute and geometric dependencies in Fig. 1. We can also use just the export/import utilities if the particular GIS do not the capability of solving the problem (Fotheringham and Wegener 2000).

The ArcGIS solution from ESRI has good support for the analysis via the scripting languages (Python, Visual Basic for Applications), all programming languages, which support component, object model (COM) and via the graphical modeling tool ModelBuilder. We also mentioned the geodatabase export/ import capabilities in the geodatabase chapter above. The standard ArcGIS analysis tools are, for example, used to create DEM and its derivates, specific tools were created such a those for morphostructural analysis (Jedlička and Mentlík 2003).

The GmIS can create many types of *graphic outputs*, which can be divided into projections of area of interest and other (i.e. graphs, statistical and tabular outputs). We further discuss just the projections:

- classical cartographical 2D outputs: groups of morphometric maps (slope, aspect, curvatures, etc.), traditional geomorphological (morphogenetic) maps or complex geomorphological map as an alternative to them,
- various types of geomorphological profiles, surface visualizations in 3D,
- animations of landform evolution (4D).

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[5] Oracle, IBM DB2, Informix, SQL Server, etc. It can also be stored as a file on the hard disc, for example in the Microsoft DataBase (<file>.mdb) format.

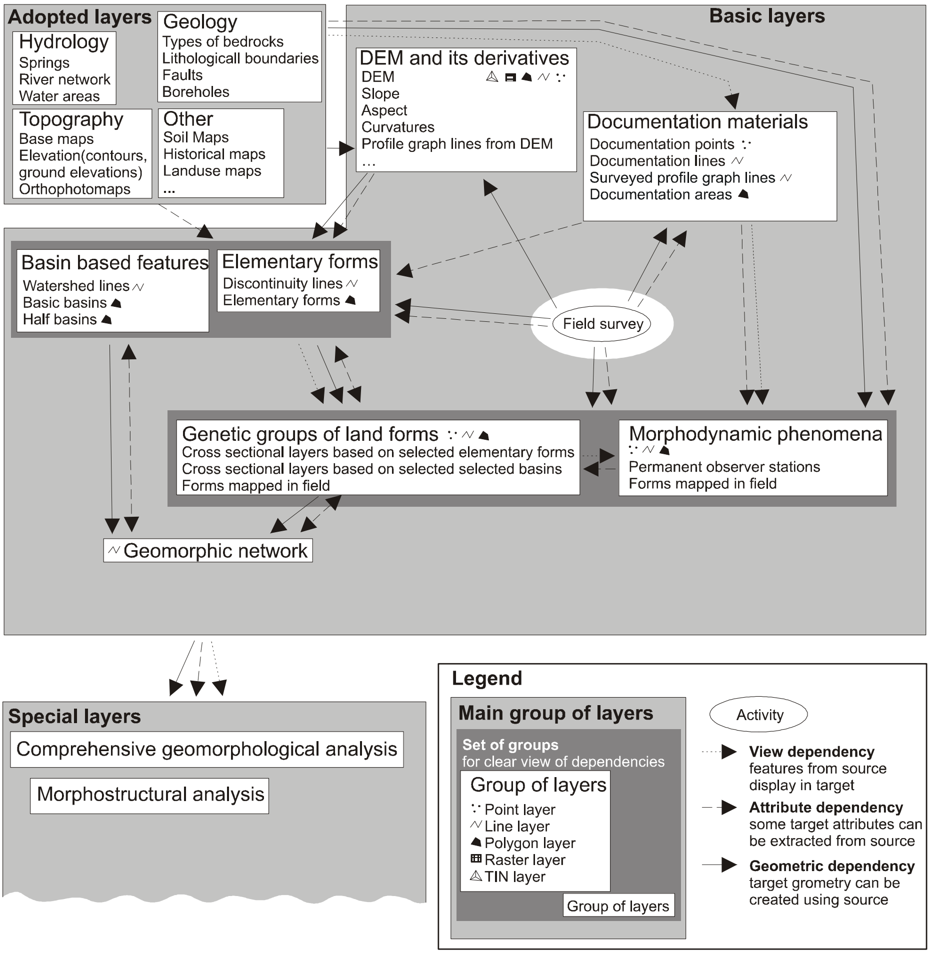

Fig. 1. The logical model of the complex geomorphological database. Just functional dependencies are highlighted and basic division into layers and groups of layers, to keep the diagram legible[6].

The GmIS, as well as other GIS types, has good support for creating any 2D graphic output. It is just necessary to respect common graphic and cartographic rules during (not only map) creation. There are rules for geomorphological maps, which can be used to create a standard legend in the GIS environment (Kusendová 2000).

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[6] Some kind of naming conventions should be used during the geodatabase design process. Conventions, which followed (ESRI 2005) and (Jedlička 2005), were used in the logical model diagram.

Good support for 3D raster or vector visualization and the fast development of functions for correct 3D visualization of raster and vector are in GIS. The situation is a little more complicated in 4D (understanding time as the fourth dimension), because at present there is no standard tool to visualize continuous (i.e. landform) evolution in time. But evolution modelling is possible using different layers for different times (which corresponds to the way that time information is stored in the GIS).

*Example of the level of data detail* can be outlined at last. The detail of all layers of the geomorphological database is determined by a scale of research, character of existing data sources and methodology of used geomorphological analysis. A level of detail equal to map 1:10 000 is used in detailed geomorphological mapping most frequently. Vector data (in this case) should be taken from the maps of the scale 1:10 000 or directly surveyed by geomorphological mapping in similar scales. The raster cell size was set to 10 m, allowing good visualization and precise analyses. Assumed precision of typical layers are described in the Tab. 3.

**Tab. 3. Assumed precision of layers in geomorphological database for target scale 1:10 000 (experiences from the surroundings of Prášilské jezero (lake) and Devínska Kobyla Mt)**

| Layers | | Precision of position | Altitude precision | Detail (scale) | Minimal size of object |
|---|---|---|---|---|---|
| *Adapted* | *Determined by technical precision (topography, orthophotomaps, hydrology …)* | from 0,5 (geodetically measured coordinates) to 20 m (roads, contour lines and other features cartographically moved due to readability) | unspecified / 1,5-7 m depending on surface slope and land cover, if contour lines are present | 1:10 000 for vector data; even 0,17 m (usually 0,5-1 m) cell size of orthophoto; | |
| | *Determined by content precision (geology, …)* | technical (scale dependent) precision is higher than precision of methods of data collecting; it is necessary to validate these data by another way | | | |
| *Basic* | *Digital elevation model* | depends on height data source; 0,5-20 m for contour lines, c. 0,5 for photogrammetric data | depends on used interpolation function and data source (1,5-7 m for contour lines) | optimized for visualization in scales close to 1:10 000 | cell size 5 m |
| | *Documentation materials* | depends on surveying technology: 1-15 m various GPS; 30-50 m traditional mapping, | 10-25 m for GPS mapping or DEM dependent | optimized for visualization in scales close to 1:10 000 | from cm (depends on geomorphic importance) |
| | *Elementary forms and Basins* | depends on DEM and documentation materials | | In 1:10 000 usually 5000 m$^2$, important forms > 2500 m$^2$ | |
| | *Genetic groups Morphodynamic Geom. network* | depends on previously created surfaces, mostly elementary forms and basins | | | |
| *Special* | | depends on previously created surfaces, mostly elementary forms and basins | | | |

## CONCLUSIONS

GmIS is a tool of geomorphological research, which can create and deal with geomorphological information of different orders. The geodabase structure of GmIS is based on the layers concept with special attention paid to function relations between the layers. Hence, we can postulate an integral process, which combines information obtained by field research and computer modelling focused on geomorphological analysis in the GmIS.

This concept of geomorphological analysis is more exact then the traditional approach and it is possible to verify the analysis at any time. The abilities of GmIS are firmly rooted in the conceptual and logical structure of the model of the geodatabase. The logical model is postulated as three main groups of layers:

1) The adopted layers, which bring some basic spatial information to the system.

2) The basic layers creating the core of the GmIS. This level constitutes mainly the DEM (raster and vector form), the layer of elementary forms and also the layer of genetic group of forms. The layers are connected by relations, which represent the flux of information in the GmIS (Fig. 1).

3) The special layers, which are generated by the process of basic and applied geomorphological analysis.

The GmIS has two key parts – the DEM and its derivatives and the layer of elementary forms. The DEM has a basic role in the GmIS, because of the creation of a comprehensive (complex) map of elementary forms and also the derivation of basin based features and geomorphic network. The map of elementary forms represents the most important part of the GmIS for geomorphological analysis because of maximal concentration of geomorphologically relevant information.

Input data in the GmIS comes from different sources (field research and adopted layers in principle) and derived layers can be created in different ways, therefore metadata plays an important role in the structure of the geodatabase. If possible, metadata should be stored for every layer or object. Storing metadata can help with finding mistakes or preventing them.

It is possible to use GmIS in various ways: morphostructural or complex geomorphological analysis and geomorphological regionalization are examples. The building of these special modules presumes the creation of specific tools. Only part of them is incorporated in common GIS products at present. Thus the GmIS could be an impulse for development of GIS technology in general.

Georelief is a crucial control element in landscape. The character of other landscape elements depends on or reflects georelief. Similar information systems can also be developed for other components of natural the landscape, but GmIS seems to be especially helpful for geoecological mapping, evaluation of geohazards, creating ground planes etc.

*This paper was created in the framework of Slovak-Czech Intergovernmental Scientific-Technical Cooperation Project: "Geomorphological information system as a basis for environmental applications" number 116. Research has been supported by VEGA (grant agency of the Ministry of Education SR and Slovak*

*Academy of Sciences) – project No. 1/1037/04, by the grant of the Czech Academy of Sciences of the Czech Republic number KJB300460501 and by the Research Plan MSM 4977751301.*

## REFERENCES

ARCTUR, D., ZEILER, M. (2004). *Designing geodatabases – case studies in GIS data modeling*. Redlands (ESRI Press).

BARSCH, D., LIEDKE, H. (1985). *Geomorphological mapping in the Federal Republic of Germany*. Berliner Geographische Abhandlugen, 39. Berlin (Freien Universität Berlin).

BARSCH, D., DIKAU, R. (1989). Entwicklung einer Digitalen Geomorphologischen Basiskarte (DGmBK). *Geo-informations Systeme*, 2 (3), 12-18.

BERUČAŠVILI, N. L., ŽUČKOVA, V. K. (1997). *Metody kompleksnych fiziko-geografičeskich issledovanij*. Moskva (Izdateľstvo Moskovskogo Universiteta).

BETÁK, J. (2002). *Geomorfologický výskum a mapovanie v oblasti k. ú. Trenčianska Turná*. Diplomová práca, Prírodovedecká fakulta Univerzity Komenského, Bratislava.

BONK, R. (2002). Scale-dependent geomorphometric analysis for glacier mapping at Nanga Parbat. In Ciolli M., Zatelli, P., eds. *GRASS GIS approach. Proceedings of the open source GIS – GRASS users conference, Trento 11-13 September 2002*. Trento (Universita' di Trento), pp. 1-21.

BONK, R. (2003). *Scale dependent impact of selected factors on morphometric parameters accuracy and automated geomorphological mapping*. PhD thesis, Faculty of Natural Sciences of Comenius University, Bratislava.

BURROUGH, P. A., MCDONNELL, R. A. (1998). *Principles of geographical information systems*. Oxford (Oxford University Press).

DEHN, M., GÄRTNER, H., DIKAU, R. (2001). Principles of semantic modelling of landform structures. *Computer and Geosciences*, 27, 1005-1010.

DEMEK, J., ed. (1972). *Manual of detailed geomorphological mapping*. Brno (Academia).

DIKAU, R. (1992). Aspects of constructing a digital geomorphological base map. *Geologisches Jahrbuch*, A122, 357-370.

DOBEŠOVÁ, Z. (2004). *Databázové systémy v GIS*. Olomouc (Univerzita Palackého v Olomouci).

FOTHERINGHAM, A. S., WEGENER, M. (2000). *Spatial models and GIS: new potential and new models*. London (Taylor and Francis).

JAMIESON, S. S. R., SINCLAIR, H. D., KIRSTEIN, L. A., PURVES, R. S. (2003). Tectonic forcing of longitudinal valleys in the Himalaya: morphological analysis of the Ladakh Batholith, North India. *Geomorphology*, 58, 49-65.

JEDLIČKA, K., MENTLÍK, P. (2003). Užití některých prvků morfostrukturní analýzy v prostředí GIS. In Mentlík, P., ed. *Geomorfologický sborník 2*. Plzeň (Západočeská univerzita v Plzni), pp. 223-232.

KOREŇ, M. (1995). Svet priestorových informácií. *GeoInfo*, 2(1), 25-29.

KRCHO, J. (2001). *Modelling of georelief and its geometrical structure using DTM: positional and numerical accuracy*. Bratislava (Q111).

KUSENDOVÁ, D. (1995). Creation of environmental maps in GIS context – on the basis of complex geomorphological research. *Acta Environmentalica Universitatis Comenianae*, 4-5, 225-260.

KUSENDOVÁ, D. (2000). Digitálna legenda pre geomorfologické mapy. *Kartografické listy*, 8, 45-54.

LÉTAL, A. (2005). *Aplikace GIS v geomorfologické mapové tvorbě*. Disertační práce, Přírodovědecká fakulta Univerzity Karlovy, Praha.

LI, Z. (1990). *Sampling strategy and accuracy assessment for digital terrain modelling*. PhD thesis, University of Glasgow, Glasgow.

LONGLEY P. A., GOODCHILD M. F., MAGUIRE, D. J., RHIND, D. W. (2001). *Geographic information systems and science*. New York (Wiley).

MENTLÍK, P. (2002a). Geomorphological information system in environment of Prášilské Lake. In Kirchner, K., Roštínský, P., eds. *Geomorfologický sborník, 1*. Brno (Masarykova Universita v Brně), pp. 90-93.

MENTLÍK, P. (2002b). Contribution to geomorphology of the surroundings of Prášilské Lake (basin of Jezerní Brook). *Silva Gabreta*, 8, 19-42.

MINÁR, J. (1992). The principles of the elementary geomorphological regionalization. *Acta Facultatis Rerum Naturalium Universitatis Comenianae, Geographica,* 33, 185-198.

MINÁR, J. (1995). Niektoré teoreticko-metodologické problémy geomorfológie vo väzbe na tvorbu komplexných geomorfologických máp. *Acta Facultatis Rerum Naturalium Universitatis Comenianae, Geographica,* 36, 7-125.

MINÁR, J. (1998). Definícia a význam elementárnych foriem georeliéfu. *Acta Facultatis Studiorum Humanitatis et Naturae Universitatis Prešoviensis, Prírodné vedy, 30, Folia Geographica*, 2, 315-321.

MINÁR, J., KUSENDOVÁ, D. (1995). Komplexná geomorfologická mapa ako súčasť GIS-u. *Geographia Slovaca*, 10, 157-162.

MINÁR, J., MIČIAN, Ľ. (2002). Komplexná geomorfologická charakteristika Devínskej Kobyly 1:10 500. In Miklós, L. ed. *Atlas krajiny Slovenskej republiky*. Bratislava (MŽP SR a SAŽP), pp. 92-93.

MINÁR, J., TREMBOŠ, P. (1994). Analýza georeliéfu ako podkladu pre komplexný krajinnoekologický výskum (modelové územie “Rudno”). *Acta Facultatis Rerum Naturalium Universitatis Comenianae, Geographica*, 35, 35-49.

PÁNEK, T. (2004). Morphotectonics of the Silesian and Magura nappe in the area of the Western Beskydy Mts. (Czech Republic). *Geografický časopis*, 56, 315-335.

SCHMIDT, J., DIKAU, R. (1999). Extracting geomorphometric attributes and objects from digital elevation models – semantics, methods, future needs. In Dikau, R., Saurer, H., eds. *GIS for Earth surface systems*. Berlin (Gebrüder Borntraeger), pp. 153-173.

SKURKOVÁ, Z. (2003). *Geomorfologické mapovanie JZ časti Devínskych Karpát*. Diplomová práca, Prírodovedecká fakulta Univerzity Komenského, Bratislava.

StANKOVIANSKY, M. (1988). Exogénne reliéfotvorné procesy modelového územia Bzince pod Javorinou (Biele Karpaty). *Sborník ČSGS*, 93, 9-19.

STRAHLER, A. N. (1952). Hypsometric (area-altitude) analysis of erosional topography. *Bulletin of the Geological Society of America*, 63, 1117-1142.

TUČEK, J. (1998). *Geographic information systems: the principles and praxis*. Praha (Computer Press).

URBÁNEK, J. (1997). Geomorfologická mapa: niektoré problémy geomorfologického mapovania na Slovensku. *Geografický časopis*, 49, 175-186.

URBÁNEK, J. (2000). Geomorfologická analýza: hľadanie systému. *Geografický časopis*, 52, 197-210.

URBÁNEK, J. (2004). Analýza vybraných prejavov neotektoniky v oblasti Kojšovskej hole v širšom priestorovom kontexte. *Geomorphologia Slovaca*, 4 (2), 5-9.

VOŽENÍLEK, V. et al. (2001). *Integrace GPS/GIS v geomorfologickém výzkumu*. Olomouc (Univerzita Palackého).

VOŽENÍLEK, V., SEDLÁK, P. (2004). Mobilní geoinformační technologie v geomorfologickém mapování. *Geografický časopis*, 56, 65-81.

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# GEOMORFOLOGICKÝ INFORMAČNÝ SYSTÉM: IDEA A MOŽNOSTI PRAKTICKEJ IMPLEMENTÁCIE

V príspevku je načrtnutá koncepcia geomorfologického informačného systému (GmIS) ako špecifického GIS-u, určeného na zber, spracovanie a generovanie geomorfologických údajov o regióne, ako aj ich vizualizáciu, verifikáciu a aktualizáciu. Autori vychádzajú z domácich a zahraničných skúseností budovania veľkomierkových informačných systémov o georeliéfe, s dôrazom na realizačné predpoklady tvorby GmIS v SR a ČR.

Koncepcia je postavená na vrstvovej štruktúre geodatabázy a funkčných vzťahoch jednotlivých vrstiev, ktoré odrážajú štruktúru (postup) komplexného geomorfologického výskumu a mapovania. Definované sú tri základné skupiny vrstiev:

*Prevzaté vrstvy* reprezentujú existujúce geomorfologicky relevantné priestorové informácie, ktoré boli generované za iným účelom – topografické mapy a ortofotomapy, riečna sieť (prípadne aj pramene, zamokrené plochy a pod.), geologické údaje (mapy, vrty, profily), mapy pôd, krajinnej pokrývky a využitia zeme a podobne. Náplň tejto skupiny vrstiev závisí od existencie príslušných zdrojov (najmä analógových a digitálnych máp veľkých mierok) a koncového zamerania GmIS.

*Základné geomorfologické vrstvy* predstavujú plne alebo čiastočne nezávislé skupiny základných geomorfologických informácií o záujmovom území. Takýto charakter má podľa nás najmä týchto sedem skupín vrstiev:

1) *Komplexný digitálny model reliéfu*, ktorý zahŕňa nielen diskrétnu reprezentáciu poľa nadmorských výšok, ale aj odvodených morfometrických parametrov (sklony, orientácie, krivosti), generované profily či priestorové (3-D) zobrazenia. Je kľúčový aj pre (polo)automatizované odvodenie ďalších základných geomorfologických vrstiev.

2) *Elementárne formy* sú vrstvou elementárnych plošných geomorfologických jednotiek, definovaných konštantnou hodnotou podstatných morfometrických parametrov vo vnútri a nespojitosťou na hraniciach formy. Ich geometrická homogenita je výsledkom homogenity genetickej aj chronologickej a podmienkou homogenity dynamickej, preto sú k nim vzťahované aj tieto charakteristiky. Ich hranice možno vyjadriť ako autonómnu líniovú vrstvu, charakterizovanú tiež celým súborom relevantných atribútov.

3) *Bazény (povodia)* – prirodzené hydro-geomorfologické jednotky, ktoré reprezentujú priestorovú organizáciu najdôležitejších exogénnych procesov a štruktúru georeliéfu len čiastočne kompatibilnú s elementárnymi formami. Efektívne je rozlíšenie polobazénov (oddelených údolnicou) a medzibazénov (prislúchajú úsekom tokov vyššieho rádu), ako aj autonómnej líniovej vrstvy hraníc – všetkým možno priraďovať geometrické, genetické a dynamické atribúty, rovnako ako u elementárnych foriem.

4) *Dokumentačné materiály* – body a línie charakterizované geomorfologicky relevantnými údajmi získanými terénnym výskumom, alebo z prevzatých vrstiev. Ich naloženie na vrstvy elementárnych foriem a bazénov umožňuje genetickú, chronologickú či dynamickú interpretáciu a verifikáciu obsahu plošných jednotiek.

5) *Morfodynamické fenomény* zahŕňajú bodové, líniové a plošné informácie o výskyte súčasných geomorfologických procesov, pochádzajúce z dokumentačných materiálov, polostacionárnych a stacionárnych meraní, prevzatých vrstiev, ale aj priestorovej extrapolácie morfodynamických charakteristík na základe relevantných charakteristík krajiny (geologická stavba, krajinná pokrývka, morfometrické parametre a pod.).

6) *Geomorfologická mriežka* je generalizáciou smeru významných lineárnych elementov georeliéfu, ktorá zvýrazňuje isté princípy jeho priestorovej organizácie (veľmi často koreluje s morfotektonickou mriežkou územia). Jej tvorbu v GmIS možno objektivizovať prostredníctvom analýzy geometrických, topologických a ďalších vlastností líniových vrstiev hraníc elementárnych foriem, bazénov a riečnej siete.

7) *Genetické skupiny foriem* sú prierezové vrstvy zložené z plošných líniových a bodových foriem jednotlivých morfogenetických skupín. Ich súčasťou môžu byť jednotlivé elementárne formy, zložené formy (ak autonómna genetická interpretácia ich zložiek nie je efektívna, alebo možná), alebo typy georeliéfu. Špecifikácia týchto vrstiev silne závisí od výskumných cieľov a charakteru skúmaného územia.

*Špeciálne geomorfologické vrstvy* zahŕňajú všetky ďalšie geomorfologické vrstvy, ktoré sú tvorené účelovým spracovaním prevzatých a základných geomorfologických vrstiev. Ich špecifikácia zodpovedá použitej metodike spracovania. Príkladom je *geomorfologická analýza*, vedúca k tvorbe komplexnej geomorfologickej mapy (ako špeciálnej vrstvy GmIS), alebo morfoštruktúrna analýza, vyúsťujúca do tvorby mofoštruktúrnej mapy. Ďalšie špeciálne vrstvy môžu reprezentovať napr. geomorfologické hrozby, riziká, potenciály a pod.

*Praktickú implementáciu* GmIS možno budovať na existujúcich GIS – technológiách. Efektívne možno využiť napríklad rozšírenú a užívateľsky komfortnú ESRI Geodatabázu, ktorá umožňuje bezpečné a rýchle spracovanie priestorových dát a efektívne využitie topológie. Viaceré analytické nástroje ESRI ArcGIS-u sú priamo využiteľné pri budovaní GmIS, pričom podpora viacerých programovacích nástrojov a možnosti importu a exportu dát umožňujú budovať špecifické geomorfologické moduly, vedúce k automatizácii tvorby, verifikácie, aktualizácie a vizualizácie jednotlivých vrstiev GmIS.