Geomorphological applications of multi-model photogrammetry

Ole Humlum

The application of multi-model photogrammetry to steep cliff faces is described and examples given of the manipulation of the digitised data to produce three-dimensional terrain models, and by using other software models to estimate surface radiation balance.

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Since 1990 the author has had the opportunity of testing and using the multi-model photogrammetric method (Dueholm, 1992), which controls a Kern DSR Analytic Stereo-Plotter, to produce detailed maps of different geomorphological features in an arctic environment. The present paper presents an example of this, and summarises the main points of geomorphological experience gained during this experiment, such as the production of different types of maps and 3D-models, as well as subsequent data analysis.

Many geomorphological investigations are currently attempting to provide information on climatic developments, both in the past and in the present. Due to certain climatic feedback effects, primarily induced by changes in terrain surface albedo, climatic changes are most pronounced in arctic and antarctic environments, and climate-related geomorphology is becoming relatively important. The actual field research is, however, often seriously hampered by the quality and scale of existing topographic maps. Detailed high-quality maps are usually a prerequisite for advanced geomorphological field investigations, and the geomorphologist has often been obliged to invest several days of valuable field working time in producing them. Furthermore, normal aerial photographs are often of limited use as a mapping base due to constrictions of scale, critical terrain gradients, or time of exposure.

As an example, steep rock faces (free rock faces) and permanent snow accumulations are both active and characteristic geomorphic features of many cold-climate landscapes, and are therefore of considerable interest to the geomorphologist. Unfortunately, it is usually difficult to obtain precise topographic maps for these terrain elements. Free rock faces are very poorly seen on normal vertical aerial photographs due to their steepness (some parts may even be overhanging) or to presence of inconvenient shadows, and consequently most existing topographic maps only represent free rock faces in a very general way. As another example, snow accumulations are usually high-albedo features, and therefore often show up with little contrast in conventional aerial photographs, making it difficult or even impossible to perform topographic mapping by standard photogrammetry using normal black-and-white panchromatic photographs. In both cases, the geomorphologist is obliged to produce his own maps in the field, which at the very best is time- and labour-consuming and, at worst, especially where high free rock faces are concerned, virtually impossible.

The multi-model method offers the possibility of overcoming several of the difficulties by producing detailed topographic and geomorphological maps from normal photographs, obtained by standard hand-held 35 or 70 mm cameras. A mapping example using the multi-model method is presented below.

Mapping in Charles Polaris Dal

In order to test the geomorphological potential of the new multi-model photogrammetry method, a locality in Charles Polaris Dal, a valley in eastern Disko, central West Greenland (70°N), was chosen as a test object.

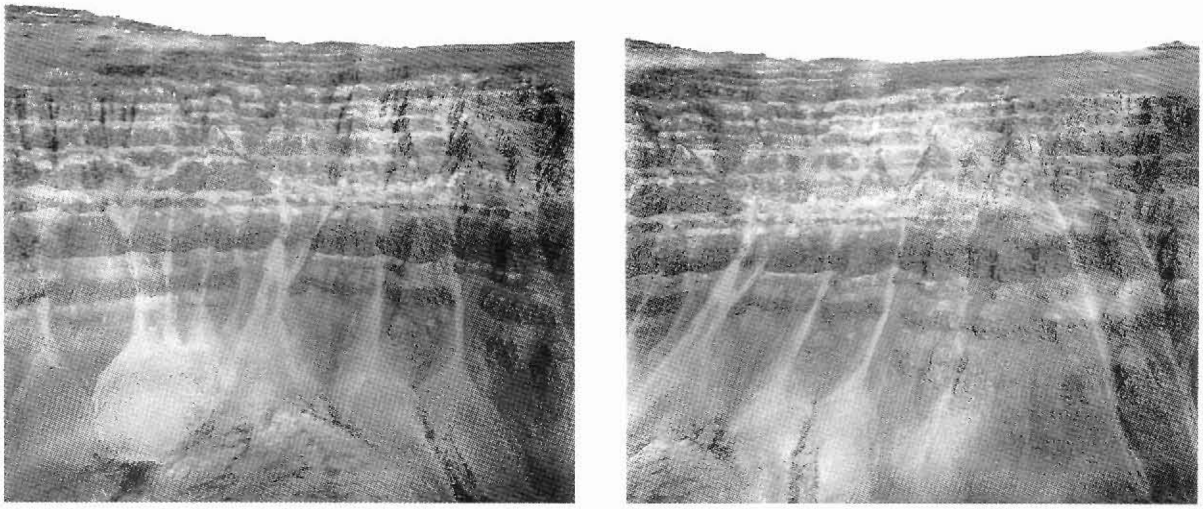

Fig. 1. Back wall of corrie in Charles Polaris Dal in eastern Disko, central West Greenland, showing the cliff face mapped by multi-model photogrammetry to give the results illustrated in Figs 2–3.

Charles Polaris Dal was glaciated during the Wisconsin, but subsequently remained ice-free during most of the Holocene, although exposed to heavy periglacial rock weathering. In general, the valley is surrounded by 300–400 m high free rock faces, cut into a gently undulating Tertiary plateau basalt landscape about 1100–1400 m a.s.l. (Fig. 1). The foot of the free rock faces is lined with large accumulations of weathered rock material (talus).

For the multi-model method, mapping material in the form of standard 70 mm colour slides taken from a helicopter was supplied by A. K. Pedersen (Geological Museum, University of Copenhagen) (Fig. 1). These slides were originally obtained for geological mapping purposes, but also appeared to represent a very useful resource for geomorphological purposes. The slides were mounted on templates and installed in a Kern DSR analytic stereo-plotter (see Dueholm, 1992). In the present case the templates with slides had been orientated during a previous geological mapping session and could thus be used immediately for geomorphological mapping purposes.

Using a strip of 7 models consisting of 8 colour slides, topographic and geomorphological mapping covering a 2500 m long section of the free rock face was completed within two working days by a non-experienced operator (the author) on the analytical plotter. The time necessary for the initial set-up of the models is not included. For a detailed description of the set-up procedure and orientation of the model see Dueholm (1992).

The resulting map, which also covers part of the terrain above and below the free rock face, displays the topography with a contour interval of 10 m. It probably represents one of the most detailed maps ever produced of a high free rock face in the arctic. Even some locally overhanging sections were readily mapped, a task often looked upon as very difficult when using conventional mapping techniques. This was also true for areas covered by inconvenient shadows, as the flexibility of the method makes it possible for the operator to change both the viewing scale and illumination. As an illustration of some of the potential, a section of the resulting topographic map is shown in Fig. 2. Detailed mapping of the different geomorphological surface types represented within the models (e.g. solid rock, talus, snow fields, etc.) was also carried out. Even the topographic mapping of difficult high-albedo features with only little surface contrast (e.g. snow-covered areas) turned out to be technically feasible. All observations were continuously and automatically digitised and stored in data files for later data manipulation. The operator has the choice between sampling at specified time intervals, or according to a distance/angle criterion, representing a sampling grid (see Dueholm, 1992, for further information).

One of the sophisticated features of the method is the possibility for the operator to move the floating mark from one stereoscopic model to the neighbouring model, across frame lines, without difficulty or delay. This feature is especially useful in the present context partly because in this way it was always possible to look 'on the other side' of protruding and otherwise blocking rock spurs, and partly because important surface quality borders could be mapped along their total extension without interruption. Compared to standard stereoscopic mapping techniques, this turned out to represent a most useful feature of the new method which saved considerable amounts of mapping time.

Data manipulation

Data digitising and collection are automatic throughout the mapping procedure, and data are stored in ASCII format. The multi-model program itself provides the operator with several analytical and graphical facilities, such as the generation and plotting of 3D-models, production of contour maps and profiles, and calculation of strike and dip of bedding planes, etc. designed primarily for geological application (see Dueholm, 1992; Dueholm & Pedersen, 1992). Several of these facilities are also useful within a geomorphological context.

It is easy to extract the resulting data files for use with other types of software for general or specific scientific purposes other than geological. The operator thus has the opportunity to make subsequent data manipulation on his own PC, and is therefore independent of subsequent access to the larger system computer, thus leaving the system computer and the multi-model software to be used more efficiently for pure mapping purposes. The present author has tested the use of data files obtained by the multi-model program on different PC-software (DOS-based and Amiga-DOS based), and some of the geomorphological potential as well as experience gained from this will be outlined below.

On a normal PC, the digitised data can be imported as ASCII-files by standard spreadsheets (e.g. Lotus 123 and Quattro Pro) running under DOS. With the mapping data successfully imported into a spreadsheet, a conversion of the ASCII values to numeric units may be carried out, whereafter several parameters, such as mean altitudes and surface areas, can be calculated directly or with very little programming of the spreadsheet. More important, however, is that most modern versions of PC-based spreadsheets are able to generate a data output in several user-specified file formats. By this the data obtained by the multi-model program may subsequently be exported to different types of special, or general, scientific software applications, as e.g. statistical software or GIS systems (Geographical Informa-

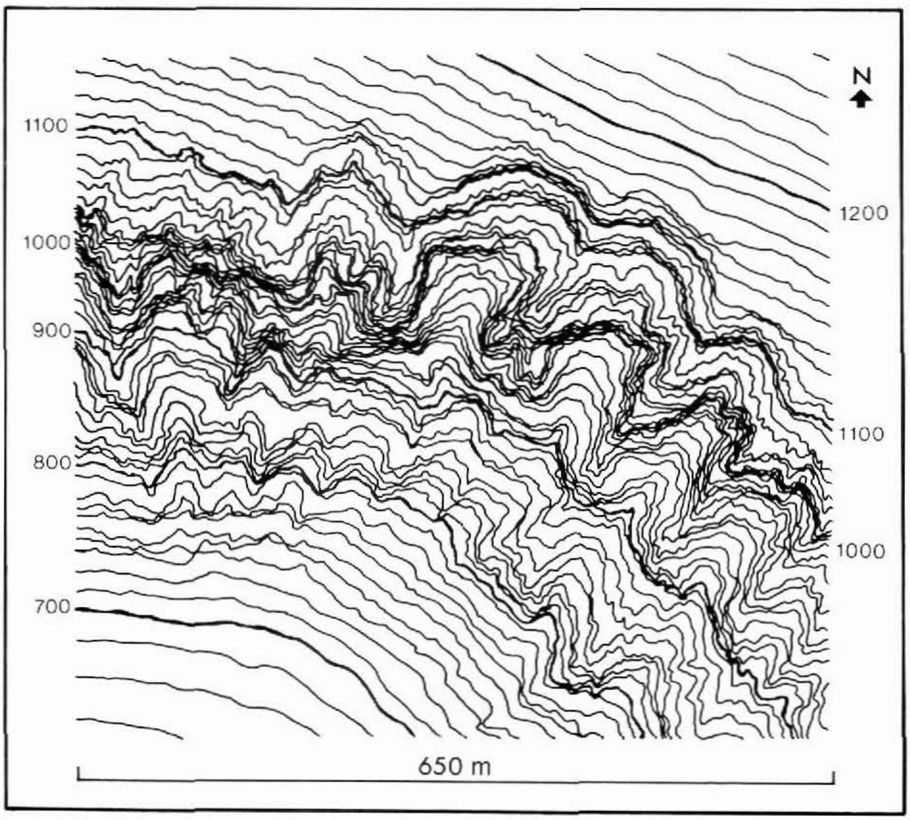

Fig. 2. Part of the topographic map with contour interval of 10 m of the rock face visible in Fig. 1. Altitudes in metres above sea level.

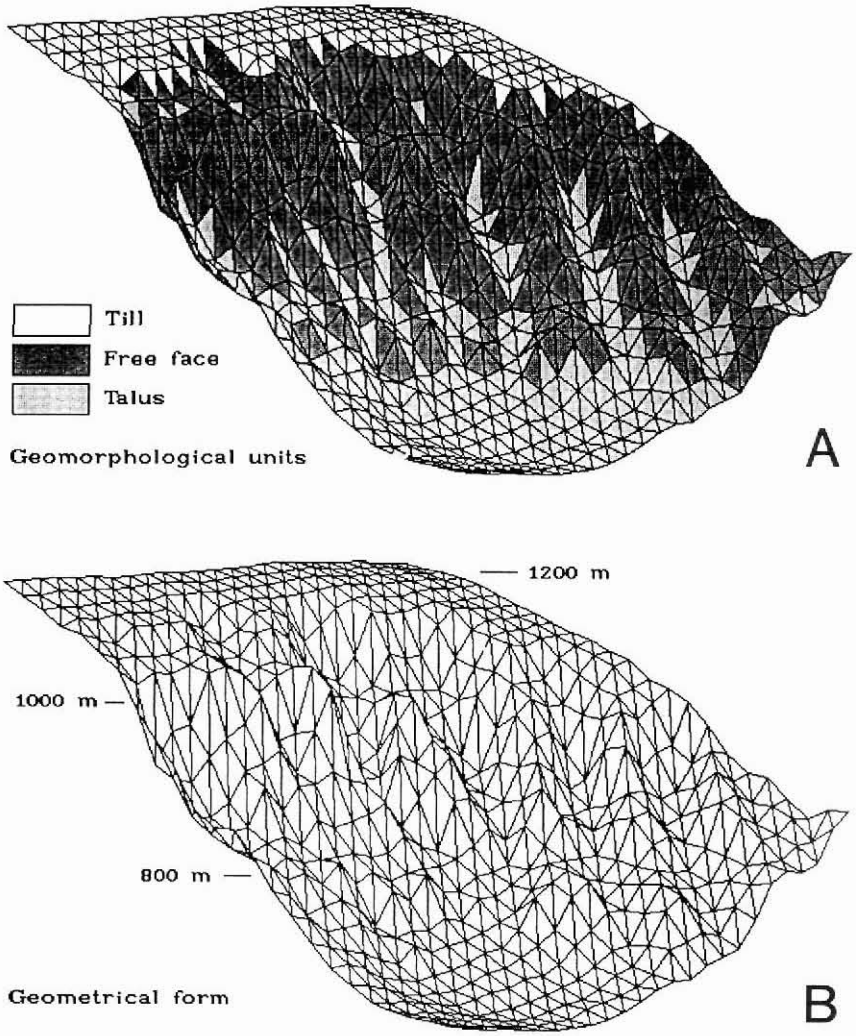

Fig. 3. Three-dimensional models showing part of the topographic map in Fig. 2. The upper model shows the main geomorphic surface characteristics. The lower model is a pure geometrical net model. Both models are viewed from the south-west, and are presented without vertical exaggeration. Horizontal dimensions 500 × 500 m. Models produced by the GeoSurface program.

tion Systems). Some special applications may even be able to import the original data generated by the multimodel program without any transformation whatsoever.

In the present context, as an experiment, the original digitised data were imported as ASCII files by the spreadsheet Quattro Pro v.2 (Borland International, USA). Here, the data were converted into numerical values, and then exported to the statistical software Statgraphics v.4.1 (STSC, USA), in order to investigate, e.g. altitudinal distribution. The data were further exported to the graphic software Surfer v.4 (Golden Software Inc., USA), by way of which it is possible to generate 3D contoured or grid models of mapped terrain features, to make user-specified cross-sections and to compare volume changes between two surveys of the same terrain feature, or to compute areas and volumes involved in specified cuts and fills. These two types of software can possibly also be of considerable use within a geological context.

Further, the application of the multi-model program data files has been tested against one of several GIS systems presently available (GeoSurface v.1.3, Zefyr, Denmark). By this application gridded or filled 3D-models may be generated, scaled and rotated. Also slope and aspect may be calculated for all individual terrain segments within the model (GeoSurface works with triangles rather than squares as several graphic and/or GIS programs unfortunately do). As an example, Fig. 3 displays a 3D grid-model of the topographic map section shown in Fig. 2. The data files concerning different surface characteristics generated by the multimodel program may also be used by the GeoSurface program, thus providing the information necessary for the compilation of geomorphological maps and 3Dmodels (Fig. 3). From this, surface albedo values are automatically attached by the software to all surface segments within the model considered. The net radiation may subsequently be calculated for all individual terrain elements within the mapped region, the GeoSurface software automatically taking into consideration the effect of different sun positions and checking for topographically induced shadow. The operator only specifies the actual calculation time (hour, day, month or year) and the associated degree of cloud cover. Furthermore, data files with climatic data can be used by the GeoSurface program to simulate a time-specific snow cover of the landscape, in order to improve the above calculations. Data files containing all the above calculated surface characteristics can then be generated by the software, and eventually exported to statistical software packages for further data analysis.

Conclusions

Briefly, the experiments up to now with the multi-model software as well as the resulting data files, enable the author to draw the following conclusions, as seen from a geomorphological point of view:

1: Multi-model photogrammetry makes it possible to make detailed topographic and geomorphological maps from user-specified test sites and/or from remote areas.

2: Multi-model photogrammetry makes possible the topographic and geomorphological mapping of certain difficult terrain features, such as steep rock faces and high-albedo snow areas.

3: Multi-model photogrammetry frees valuable measuring time in the field, as only slides obtained from a standard hand-held camera are required. Subsequent mapping is carried out in a photogrammetrical laboratory.

4: Multi-model photogrammetry makes it possible to use material (slides) obtained by others; even though the photographs were made for a completely different purpose.

5: Multi-model photogrammetry output in the form of data files may be used as base-line data for advanced geomorphological analysis. By exporting the data files to other software the occurrence of different terrain elements, e.g. snow fields, glaciers, rock glaciers or even certain biologic units, can be analysed spatially or geometrically and correlated, for example, with the local radiation balance for any user-specified time or period. Also statistical analysis and comparisons with earlier maps are made considerably easier.

Summing up, the multi-model mapping technique provides a professional situation only dreamt of by geomorphologists (and probably also biologists) a few years ago. As new supplementary scientific software tend to be published at an ever increasing speed, the geomorphological potentials of this new mapping technique will probably increase even further in the years to come.

References

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