Swissalti3D : a new tool for geological mapping

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swissALTI3D – a new Tool for geological Mapping

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Abstract

With the 2013 publication of swissALTI3D, Switzerland has for the first time at its disposal a high resolution digital terrain model, which is regularly updated and which covers the whole of Switzerland comprehensively. The former shortcoming regarding the poor data quality in the areas above 2,000 m above mean sea level (amsl) has been rectified by swisstopo for this new publication.

In this article we show how geologists may benefit from this product. The editors of the Swiss Geological Survey (SGS) as well as the external authors of our maps are already actively using the model and could thereby gain valuable experience. The new geological maps therefore display, at all elevations, accurately positioned morphological details which for example, provide a valuable service for hazard mapping. The interpretation and mapping of quaternary landforms based on the analysis of swissALTI3D as presented by means of some illustrative examples demonstrates the high level quality of the actual production of the Geological Atlas of Switzerland 1:25'000 (GA25) by the SGS. Furthermore swissALTI3D represents a powerful tool for the future revision of older geological maps recently vectorized in the frame of the nationwide project GeoCover.

Zusammenfassung

Mit der Publikation von swissALTI3D 2013 verfügt die Schweiz erstmals über ein hoch auflösendes digitales Terrainmodell, welches regelmässig nachgeführt und flächendeckend über die ganze Schweiz zur Verfügung steht. Der Mangel der schlechteren Datenqualität in den Gebieten oberhalb von 2'000 m ü. M. konnte von swisstopo für die neue Publikation behoben werden.

In diesem Artikel zeigen wir, wie auch Geologen von diesem Produkt profitieren können. Die Redaktoren der Landesgeologie sowie die externen Autoren unserer Karten setzten das Modell bereits rege ein und konnten damit wertvolle Erfahrungen sammeln. Die neuen geologischen Karten zeigen deshalb in allen Höhenlagen lagegenaue morphologische Details, welche z.B. für die Gefahrenkartierung wertvolle Dienste leisten. An illustrativen Beispielen werden Interpretation und Kartierung der quartären Landschaftsformen basierend auf der Auswertung von swissALTI3D präsentiert. Diese Beispiele demonstrieren eindrücklich die hohe Qualität der heutigen Produktion des Geologischen Atlas der Schweiz 1:25'000 (GA25) durch die Landesgeologie. Zusätzlich stellt swissALTI3D eine sehr gute Grundlage für die zukünftigen Revisionen älterer geologischer Karten dar, welche im Rahmen des Projektes GeoCover flächendeckend für die gesamte Schweiz digitalisiert wurden.

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1 Introduction

The comprehensive swissALTI3D digital elevation model describes the surface of Switzerland and Liechtenstein without vegetation and infrastructure. It has been available since the start of 2013 for all elevations with a high level of precision. swissALTI3D is updated in a 6-year cycle whereby in future, chronological comparisons of the landscape will also be possible.
In contrast to its previous version, in which the «digitales Höhenmodell (DHM25)» was still used as a basis for elevations above 2,000 m above mean sea level (amsl), the new elevation model in the whole of the pre-alpine and alpine territories is based on aerial photograph strips from the years 2008 to 2011, with a surface resolution of 50 cm. With the help of stereo-correlation, the new digital terrain model could be derived from it.
Fig. 1 shows the update status of the data split up by zones.
Since 2008, swissALTI3D has been updated in a 6-year cycle on the basis of aerial photographs. The years correspond in each case to the flight years; analysis is performed in the year thereafter and the data is published at the beginning of the year after that.

2 Methods, Accuracy and Limitations of swissALTI3D

2.1 Survey Methods and Altimetric Accuracy of swissALTI3D

Fig. 2 shows which data and methods form the basis of swissALTI3D in the various regions of Switzerland:
- DTM-AV (LIDAR): The data were imported from DTM-AV. No updating has been carried out. [DTM-AV: digitales Terrainmodell der amtlichen Vermessung; LIDAR: Light Detection and Ranging].
- DTM-AV with photogrammetric update: The data were updated based on current aerial photographs.
- Stereo-correlation: The DHM25 data have been replaced by more accurate data, based on the stereo-correlation of aerial photographs.

As a result of the different underlying data sources and survey methods, swissALTI3D has no uniform accuracy. To sum up, the accuracy can be described as follows:
- Below 2,000 m amsl: ± 50 cm 1σ
- Above 2,000 m amsl: ± 1–3 m 1σ.

Due to the absence of reference values, the altimetric accuracy of swissALTI3D could up to now not be verified comprehensively.

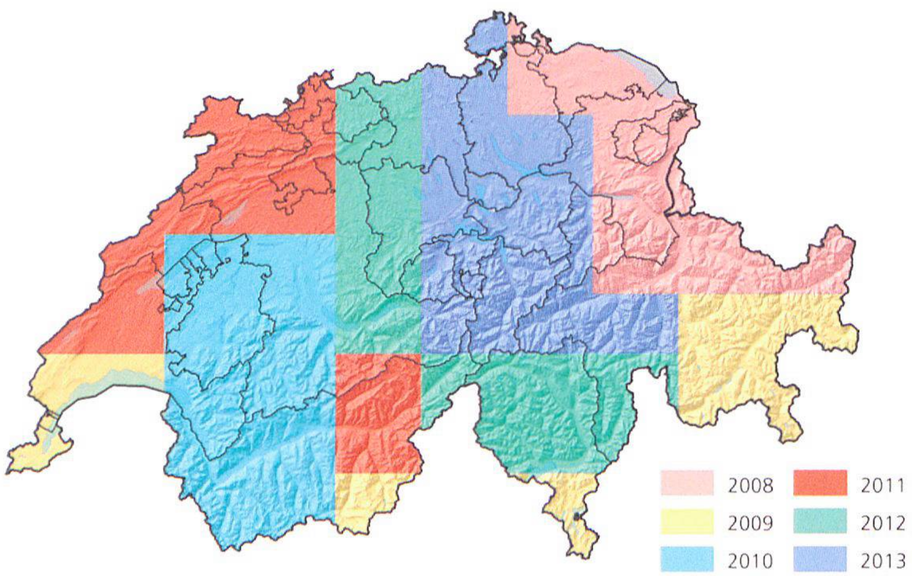

Fig. 1: Update status of the swissALTI3D data (flight year).

However, locally conducted checks confirm the values stated above.

2.2 Limitations

The aerial photographic data used for this model were captured during the years 2008–2011. This led to different snow and ice cover states between the individual update blocks, which resulted in uneven transitions along the block borders. Elevation differences and abrupt transitions could also not be avoided in certain areas within individual production blocks above 2,000 m amsl.
In addition, elevation differences exist in some regions between the DTM-AV and the stereo-correlation data because of these snow and ice coverage issues. Once more, the reason is the different recording times, this time between the LIDAR and the photographic aerial surveys.
The data imported from the DTM-AV are continuously updated. In areas in which a height difference of more than ± 50 cm is detected, the points are removed and new points, break lines and surfaces are recorded. In parallel to updating the DTM, improvements are made to the original laser generated terrain model. For example, the modelling of the DTM was improved around bridges and enclosing break lines (exclusion areas) introduced for lakes.

2.3 Formats and Data Provision

SwissALTI3D is provided in three resolutions (raster), i.e. 2 m, 5 m and 10 m. It can be obtained both as a complete data set for the entire Switzerland as well as in the form of smaller areas (cantons, municipalities, rectangular areas with a minimum size of 1 km^2). The data is provided by swisstopo in the following formats: Geotiff, ESRI ASCII GRID, ESRI File Geodatabase 10.1 and ASCII XYZ single space. The elevation models are available in both the LV95 (CH1903+) LN02 datum as well as the LV03 (CH1903) LN02 datum.
Further information on swissALTI3D can be found under www.swisstopo.ch/height. The

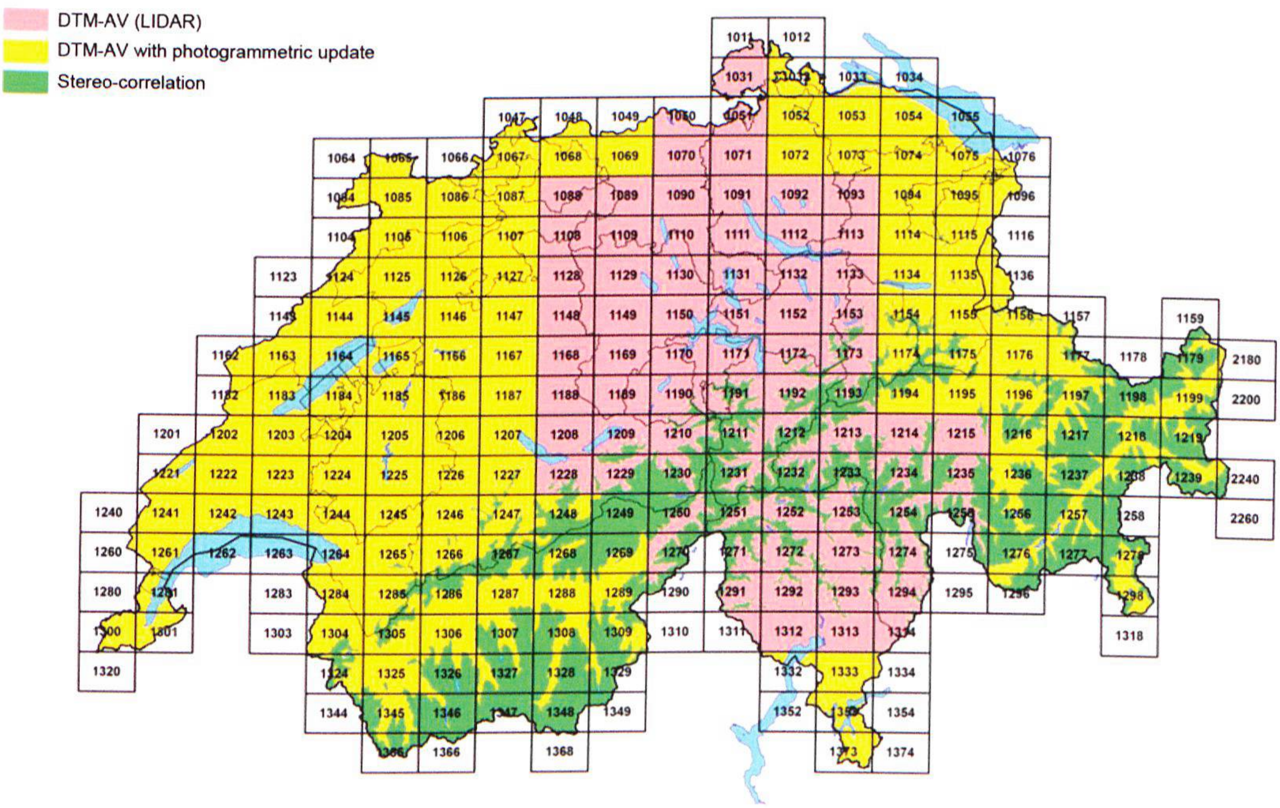

Fig. 2: Data basis and methods used for swissALTI3D.

data can also be ordered directly from the Toposhop (www.toposhop.admin.ch) as CD/DVD or via download. The staff of the Swiss Geological Survey (infogeol@swisstopo.ch) and the Geographical Data Distribution centre (geodata@swisstopo.ch) are available to deal with your queries.

3 Application and Advantages of swissALTI^{3D} for the Production of Geological Maps

The analysis and interpretation of digital elevation models in combination with ortho images (undistorted aerial photographs) is a

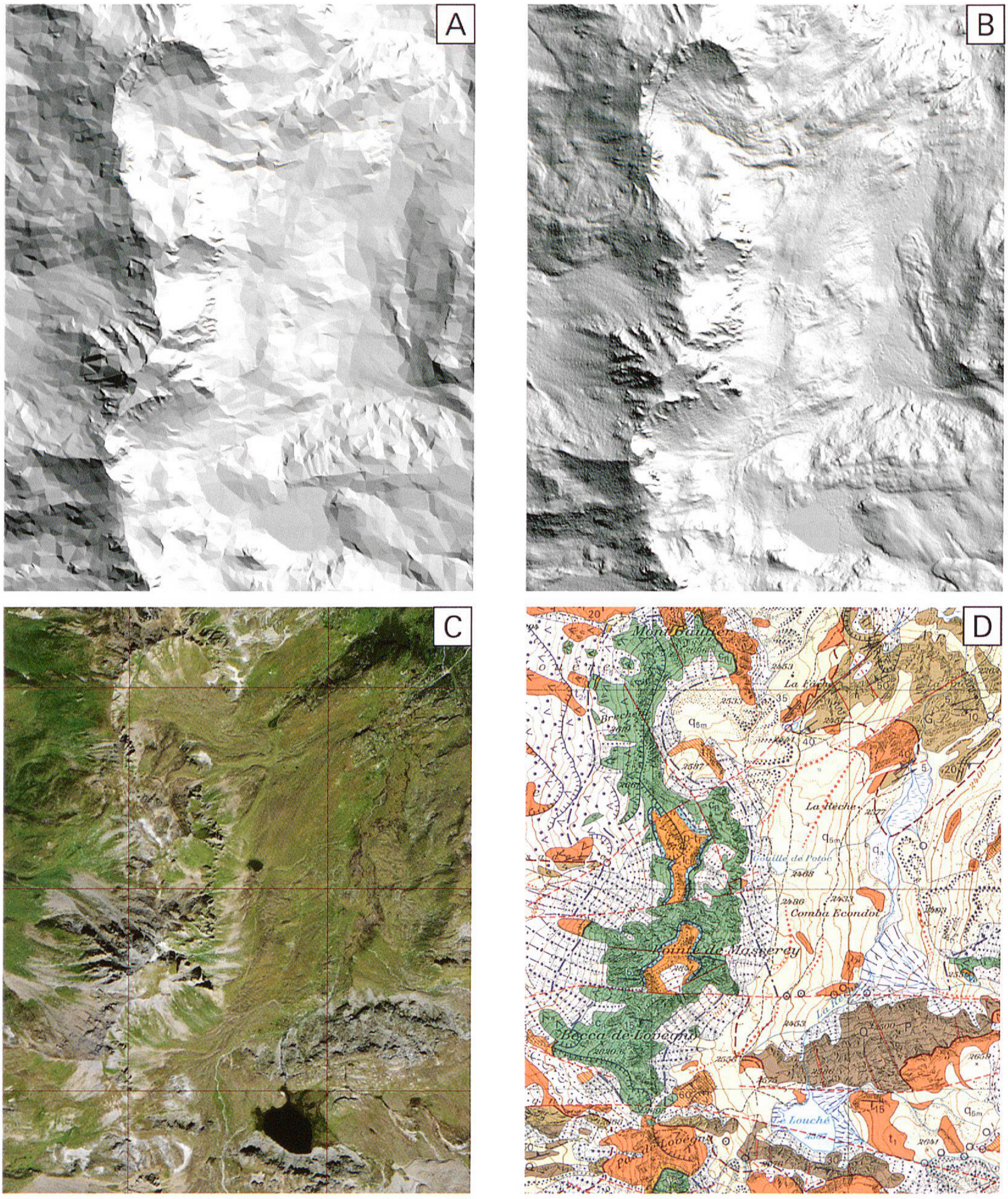

Fig. 3: Comparison of [A] the digital elevation model (DHM25); [B] the high resolution swissALTI^{3D} and [C] ortho image used for interpretation and mapping of quaternary landforms displayed on a [D] geological map (extract of map 122 Vissoie; Marthaler et al. 2008).

standard procedure in the present day production of the Geological Atlas of Switzerland 1:25'000 (GA25). It is used especially for mapping and editing of quaternary landforms with minor importance of bedrock information (e.g. delimitation of bedrock and unconsolidated deposits). The potential of stacking different georeferenced data in multi-layer projects enables digitizing the locations of quaternary features as accurately as possible.

The poor resolution of the DHM25 above 2,000 m asml didn't allow for the precise analysis of quaternary landforms and therefore additional information were restricted only to the interpretation of ortho images (Fig. 3A, C). A comparison of the existing elevation model and the newly launched swissALTI^{3D} as shown in Fig. 3A and B clearly demonstrates the great advantage of swissALTI^{3D} for the production and revision of geological maps if combined with the analysis of ortho images (Fig. 3C, D).

In the following paragraphs, some examples will be given demonstrating the wide and powerful use of swissALTI^{3D} for mapping of quaternary landforms as displayed on geological maps of GA25. Each example will be illustrated in the same way: The general morphology which is deduced from the generated hillshade based on swissALTI^{3D} is first discussed, followed by the interpretation of quaternary landforms as well as the presentation on the map of GA25 (Fig. 4). All of these examples originate from the geological map of Vissoie (Marthaler et al. 2008) and are grouped into gravitational and fluviatile deposits, glacial and periglacial morphologies and slope instabilities. Characterization and presentation of quaternary morphologies for the GA25 are given in BWG (2003). Note that the interpretation of morphologies shown in Fig. 4 is mainly based on mapping in the field; the additional analysis of ortho images as well as high resolution digital elevation models enables accurate presentation in map view (e.g. delimitation and positioning of map units) and were mostly applied during the map sheet editing process.

3.1 Gravitational and Fluviatile Deposits

Examples of different morphologies and their classification based on the analysis of swissALTI^{3D} are shown in Fig. 4A–C. We focus on the main types of accumulation of gravitational and fluviatile deposits i.e. alluvial fan, mixed cone (alluvial and debris cone) and debris (talus) cone.

In the first view, the characteristic smooth morphology of cones and fans can be recognized easily in a hillshade view based on swissALTI^{3D}. They are clearly distinguished from the surrounding moraine deposits and bedrock outcrops which are characterized by irregular and undulated surfaces. In greater detail these cones and fans show different morphological features which are directly linked to their origin and therefore can be used for interpretation and classification of quaternary deposits.

Some cones show a uniform and rather smooth appearance with very finely defined downward striae, e.g. in the lower left of Fig. 4A. The absence of well-established channels, which are typical for fluviatile processes, implies that the formation of these cones is mainly driven by pure gravitational processes without a major fluviatile component. Consequently these cones have been interpreted as debris cones (displayed as dotted lines).

On the other hand, some cones and fans show a rather irregular and undulating surface representing a well-established net of channels, often appearing quite similar to a braided river system, e.g. in the central left-side of Fig. 4A. The existence of these channels clearly indicates that transportation and deposition occurred dominantly by fluviatile processes. Hence these morphologies are attributed as alluvial fans (displayed as dashed blue lines).

In between the two end members, debris cone and alluvial fan, a wide range of socalled mixed cones can be distinguished. These mixed cones are characterized by a mixture of gravitationally transported and deposited material (mainly rock falls) and superimposed temporary fluviatile components. Mixed cones generally show the same uniform and smooth appearance of debris cones but additionally, individual channels have evolved due to episodic water activity (upper middle of Fig. 4A). Generally mixed cones show a bivalent character from top to bottom: The upper part normally is domi-

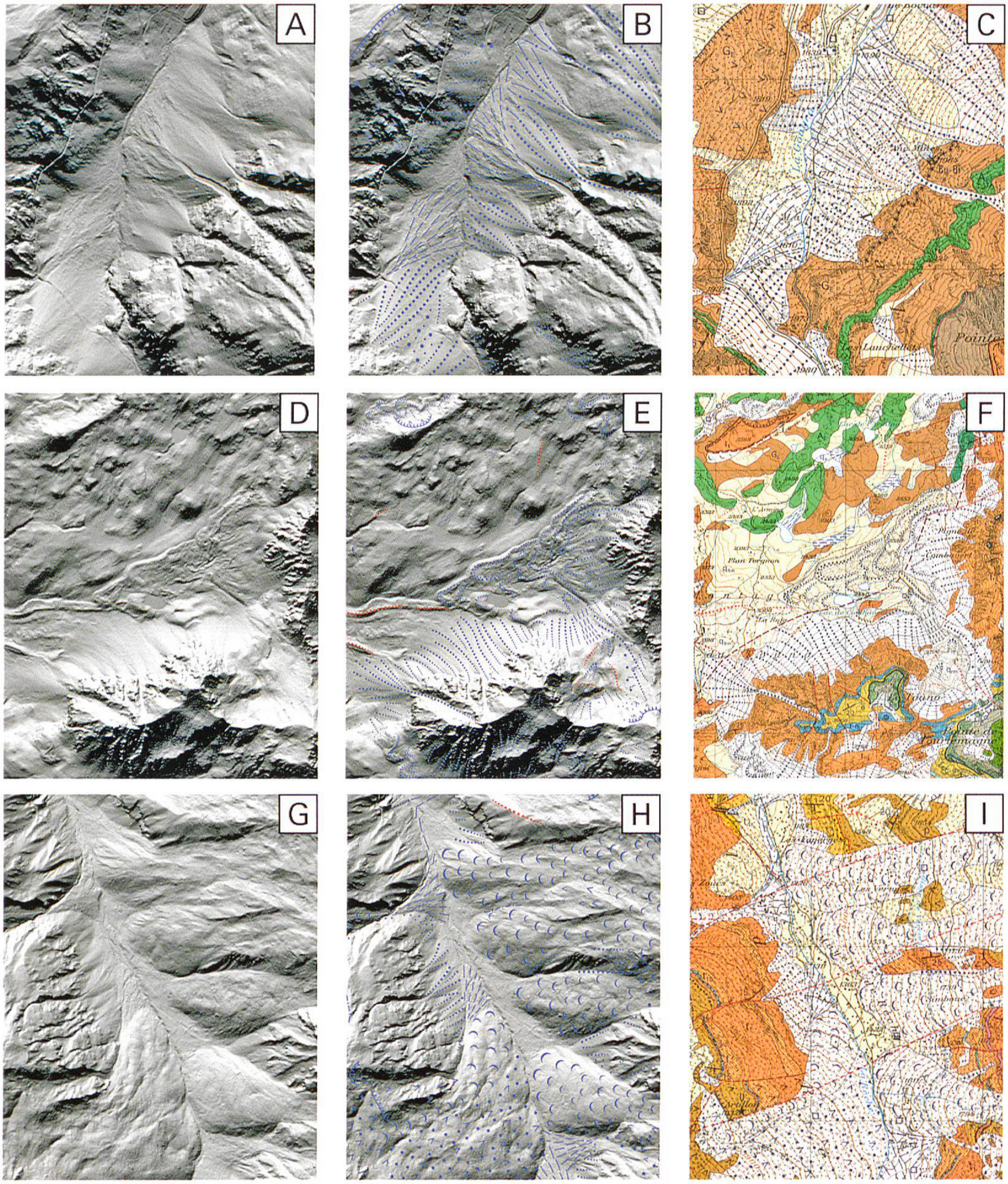

Fig. 4: Analysis and interpretation of quaternary landforms using hillshade view based on swissALTI3D and presentation on a geological map (extract of map 122 Vissoie; Marthaler et al. 2008). [A] – [C] gravitational and fluviatile deposits; [D] – [F] glacial and periglacial deposits; [G] – [I] slope instabilities. See text for legend.

nated by gravitational processes whereas towards the lower part increasing significance of transportation and deposition by water is observed. This bivalent character is taken into account by using different symbology as shown in Fig. 4B and C (dash-dotted lines). Identification of mixed cones cannot only be performed by analysis of the digital elevation model, additional information from field, ortho images and topography is necessary.

3.2 Glacial and Periglacial Deposits

In the second example, we focus on quaternary morphologies formed in a glacial and periglacial environment. Typical for such an environment are laminar deposits of moraine with characteristic ridges and lobes (shown as red dotted lines), both visible in hillshade view (Fig. 4D–F). Again the unconsolidated deposits can be clearly distinguished from the outcropping bedrock by the strongly contrasting morphology as visible in the lower part of Fig. 4D.
The great advantage of swissALTI^{3D} is the recognition and outline of different glacial stages simply based on morphologies and trend of associated ridges and lobes. An example is shown in the center of Fig. 4D: In the upper part the surface shows an undulated, rather uniform and smooth morphology related to moraine of the Last Glacial Maximum (LGM) which has been cut off and overlain by a younger stage, characterized by a much stronger relief and nicely developed ridges attributed to a Late Glacial event. Towards the right a large system of lobes clearly related to a rock glacier (blue dotted double lines) seems to creep downwards over both the moraine of the LGM and the Late Glacial. Towards the surrounding cliffs the glacial and periglacial deposits have been progressively covered by talus and debris cones (displayed as blue dotted lines), as shown in Fig. 4D and E.

3.3 Slope Instabilities

The analysis of swissALTI^{3D} high resolution digital elevation model can also be used for recognition and mapping of slope instabilities such as masses of landslide and block-glide. In the examples shown in Fig. 4G–I several slope instabilities are arranged together. Landslide masses are generally easily identifiable as lobe-shaped morphologies (displayed as oriented crescent-shaped symbols; Fig. 4G–H). The characteristic shape intuitively points to large, generally completely dismembered masses creeping and flowing down the slopes into the valleys. On the right side of Fig. 4G four lobes can be distinguished based on their morphology, which clearly contrasts with the outcropping bedrock of the slopes.
An example of a block-glide mass (displayed by oriented v in Fig. 4H and I) is distinguishable on the lower left side of Fig. 4G. Compared to landslides, which consist of a completely dismembered rock mass, a block-glide mass generally represents a coherent rock body. This difference is also visible in swissALTI^{3D}. The morphology of block-glide masses is normally characterized by an irregular and undulating surface. On the left side of Fig. 4G the progressive evolution of a block-glide mass is illustratively shown: In the middle left the outcropping bedrock appears to be rather stable as indicated by a continuous running relief. Towards the lower left the progressive evolution of a block-glide mass is visible, ranging from individual coherent blocks to completely shattered and dismembered rock bodies. Superimposed on the block-glide, an additional landslide is recognizable as a rather faint lobe (Fig. 4G and H).
In addition, landslide scars are clearly visible.

4 Concluding Remarks and Outlook

As presented and discussed in the above section, swissALTI^{3D} is an important and powerful tool for the production of geologi-

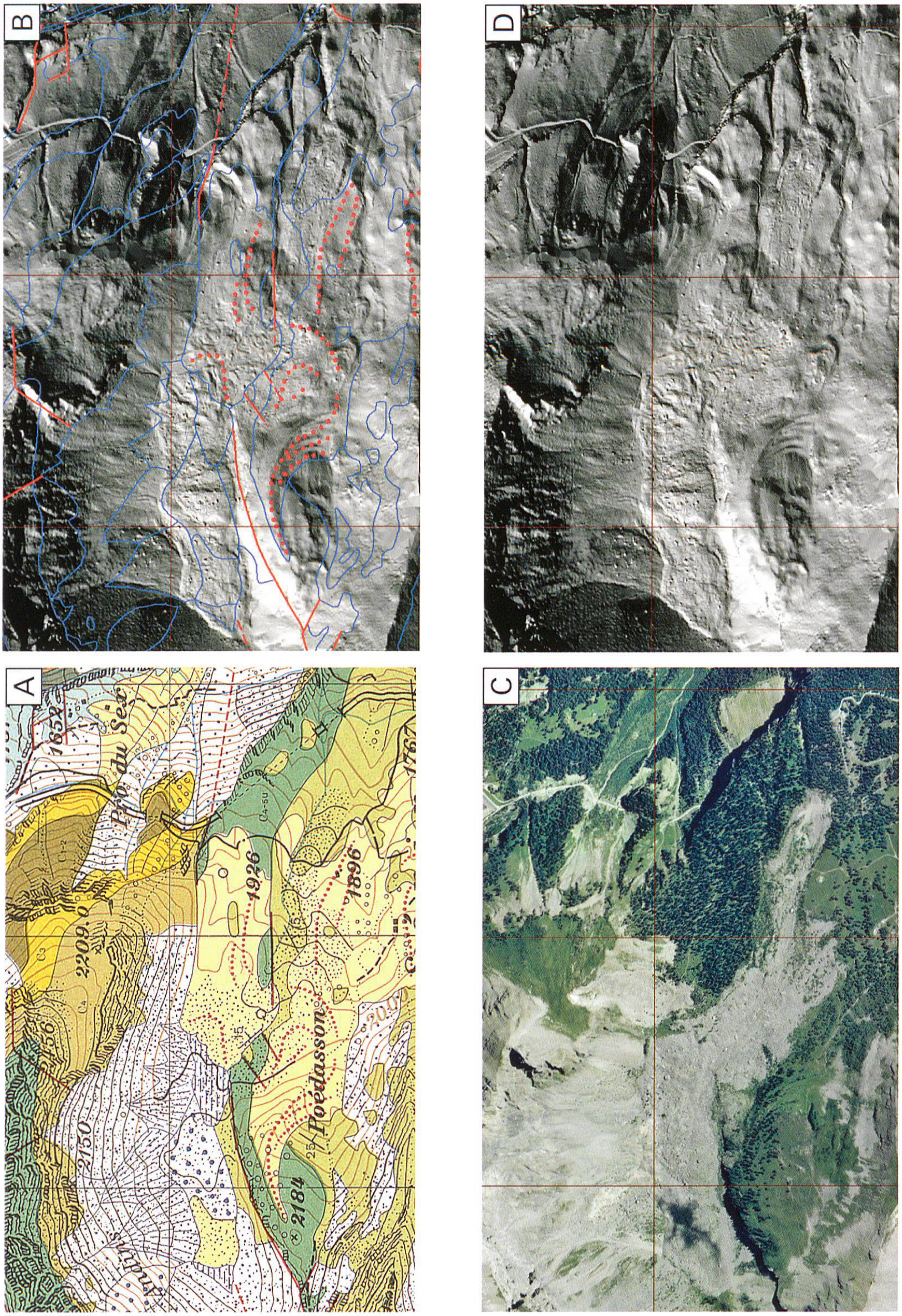

Fig. 5: Comparison between an ancient map sheet of the GA25 with swissALTI3D and ortho image. [A] ancient geological map (extract of map 35 St-Léonard; Badoux et al. 1959); [B] geological contours of the vectorized map and underlying swissALTI3D; [C] ortho image; [D] hillshade view based on swissALTI3D.

cal maps, especially for analysis and mapping of quaternary landforms. Consequently the Swiss Geological Survey (SGS) will use swissALTI^{3D} by default during the editing process of forthcoming map sheets of the GA25 to improve the quality.
Additionally swissALTI^{3D} can be used for revising existing map sheets of the GA25. In 2009 the SGS launched the GeoCover project with the aim of providing geological vector datasets covering the whole of Switzerland at the best available quality by the end of 2012. The GIS data set includes all existing map sheets of the GA25 as well as compilations in the remaining areas. With the completion of the project GeoCover a digital revision especially of the ancient, now vectorized map sheets of the GA25 will be possible and explicitly needed by comparison with the available swissALTI^{3D}.

Fig. 5A–D presents a comparison between an ancient map sheet, ortho image and swissALTI^{3D}. The selected map extract originates from the GA25 map sheet St-Léonard (Badoux et al. 1959; Fig. 5A) south of Six des Eaux Froides near the Rawilpass. The comparison between the geologic contours of the vectorized map and swissALTI^{3D} shows obvious discrepancies, especially for the outlines of quaternary landforms and the limitation between outcropping bedrock and unconsolidated deposits (Fig. 5B). Serious differences are detected in the lower right where two well evolved lobes of a rock glacier, with several corresponding ridges, can be clearly identified by analysis of ortho images and swissALTI^{3D} (Fig. 5C and D). Minor offsets are observed in the trend of moraine ridges and the limitation of alluvial fans in the upper center of Fig. 5B. The multiple reasons for such discrepancies are mainly due to the quality of the topographic base as well as substantial scientific advances achieved in the interpretation of quaternary processes and corresponding morphologies.
In the presented paper the use and potential of swissALTI^{3D} and its application in the production of the GA25 by the SGS has been highlighted. Combined with analysis of ortho images the high-resolution digital elevation model of swissALTI^{3D} is a powerful tool not only for mapping and editing of forthcoming map sheets of the GA25 and revision of the geological vector datasets of GeoCover but also for mapping of natural hazards (e.g. slope instabilities).

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