LiDAR, GIS and Down-Plunge Cross Sections: Examples from the Livingstone Thrust Sheet and the Morcles Nappe*

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Abstract

LiDAR images, geological mapping and down-plunge cross sections of the Livingstone Thrust Sheet (SW Alberta) and the Morcles Nappe (SW Switzerland) are presented. LiDAR presents a valuable tool to recognize features that would otherwise remain obscured by vegetation. Draping geological maps over detailed LiDAR DEM's resulted in refinements of the geological maps. Down-plunge cross sections, based on these maps combined with information from petroleum wells and seismic surveys, image the subsurface. These techniques result in accurate 3D representations of geology at surface and subsurface.

Introduction

Canadians, such as John Allan (1884-1955) and Eric Mountjoy (1931 – 2010), were great mappers of mountains. John Allan pioneered the use of aerial photographs and Eric Mountjoy (together with Ray Price) refined these techniques obtaining remarkably accurate maps. Nowadays, the use of airborne LiDAR (an acronym for Light Detection And Ranging) is becoming more common in geological mapping and results in refinement of geological maps and models.

Methodology

LiDAR systems employ intense pulses of light, typically generated by lasers, and sensitive optical detectors to receive the reflected pulses. Airborne LiDAR systems consist of a laser machine mounted beneath an airplane or helicopter that follows a predefined path. The ground is then scanned by means of tens of thousands of pulses per second emitted from the laser. In order to obtain measurements for the horizontal coordinates (x, y) and elevation (z) of the objects scanned, the position of the aircraft is determined using accurate differential GPS measurements and the distance from the aircraft to the ground calculated. A combination of LiDAR and GIS techniques allows the geology to be viewed down-plunge and to be compared to cross sections obtained by more traditional methods using software such as LithoTect and GaiaBase.

Examples

The Alberta Geological Survey purchased LiDAR data for a 33 km^2 area covering Turtle and Bluff Mountain in the Crowsnest Pass area of Alberta. Trees and buildings were removed by filtering and the resulting bare earth DEM shows details of rock structures, which are concealed in regular aerial photos mainly due to vegetation cover. Draping existing geological maps (Langenberg et al., 2007) over this DEM allows refinement of these maps (Figure 1). The trace of the Turtle Mountain Thrust as displayed on a GSC geological map (Norris, 1993) can be more accurately placed. In addition, the trace of the axial plane location of stratigraphic contacts of the Turtle Mountain Anticline can be accurately placed on the DEM. Contacts needed adjustments of up to 150 m on the existing maps.

Subsequently, cross sections including stratigraphic picks and dip-meter data plus seismic data were constructed with the help of LithoTect through the Livingstone Thrust Sheet, extending to the Triangle Zone (Figure 2).

A down-plunge cross section through the Morcles Nappe (SW Switzerland) was constructed by Langenberg et al. (1987; Figure 3). The University of Lausanne (and the Canton de Vaud) obtained LiDAR images of this area from Swisstopo, the Swiss Geo-information Centre. The geology of the 'Diablerets' map-sheet (Badoux et al, 1990; from Swisstopo) was draped over the DEM and GIS technology allowed the area to be viewed down-plunge. These views can be compared with the previously constructed down-plunge cross sections. In the Haute Pointe area, which is in the frontal part of the Morcles Nappe, the precise location of the lower contact of the Urgonian (Barremian) litho-stratigraphic unit could be shown to be 100 m southeast from the location mapped in the 1980's (Figure 4). In other areas, contacts were mapped more than 100 m away from their true location. Faults could also be located more precisely.

Conclusions

The remarkable feature about LiDAR is its capability to remove non-ground objects. LiDAR presents a valuable tool to recognize features that would otherwise remain obscured by vegetation. It is anticipated that this technique combined with improved cross-sectioning methods will revolutionize geological mapping and result in accurate 3D representations of geology at surface and subsurface.

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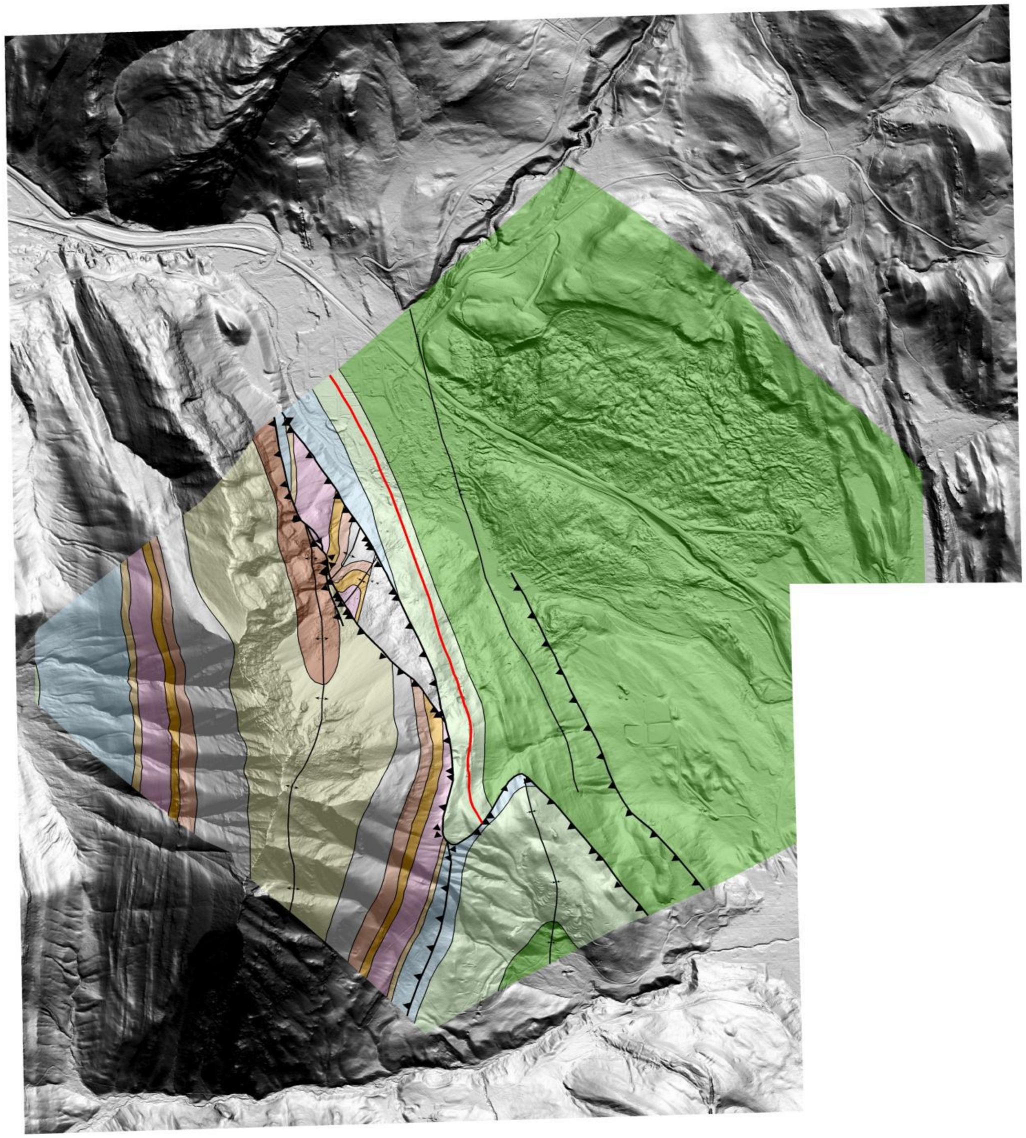

Figure 1. Geology draped over LiDAR image of the Turtle Mountain area (with trees removed).

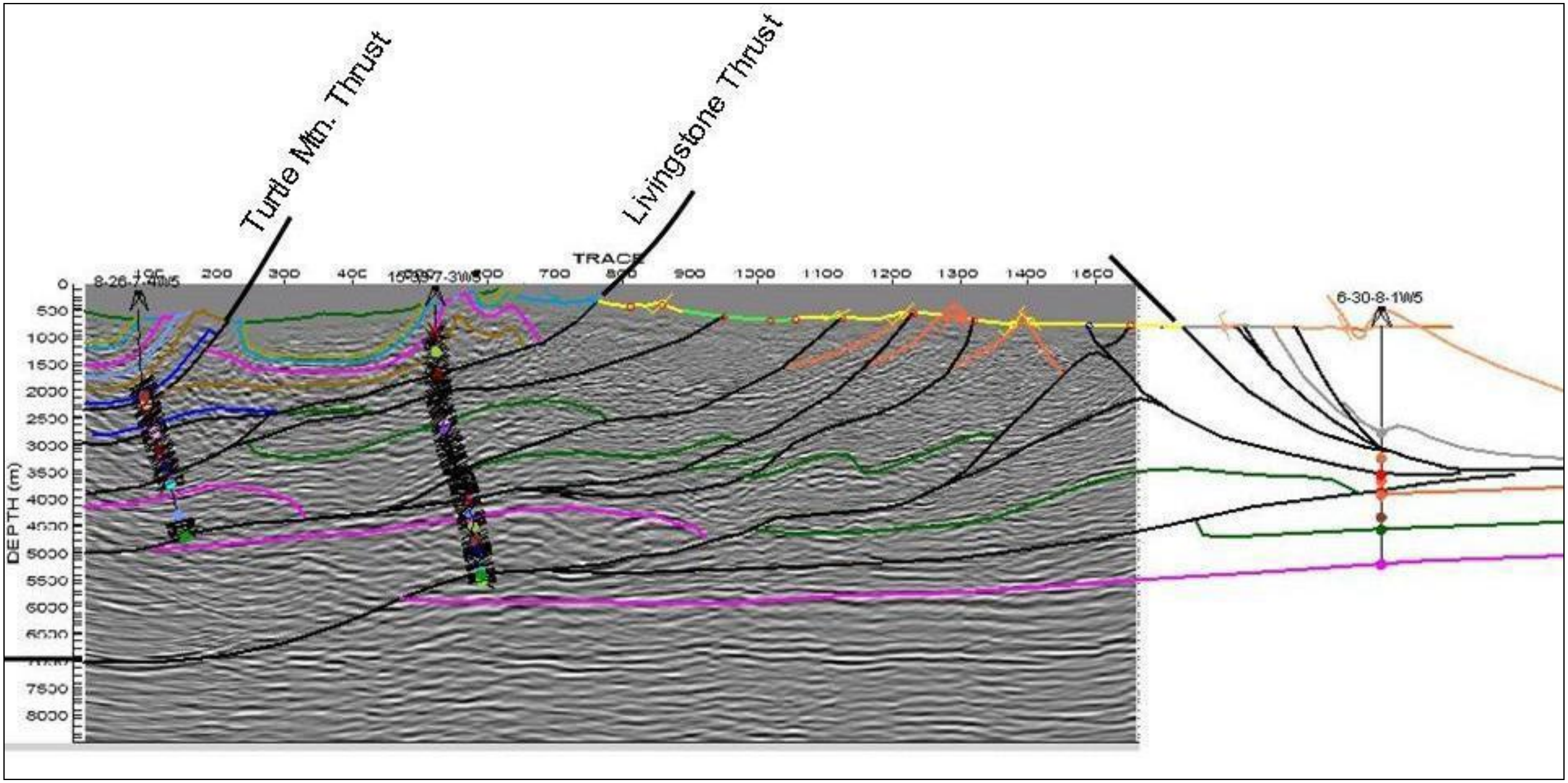

Figure 2. Cross section including well information and seismic data through the Livingstone Thrust Sheet and Triangle Zone.

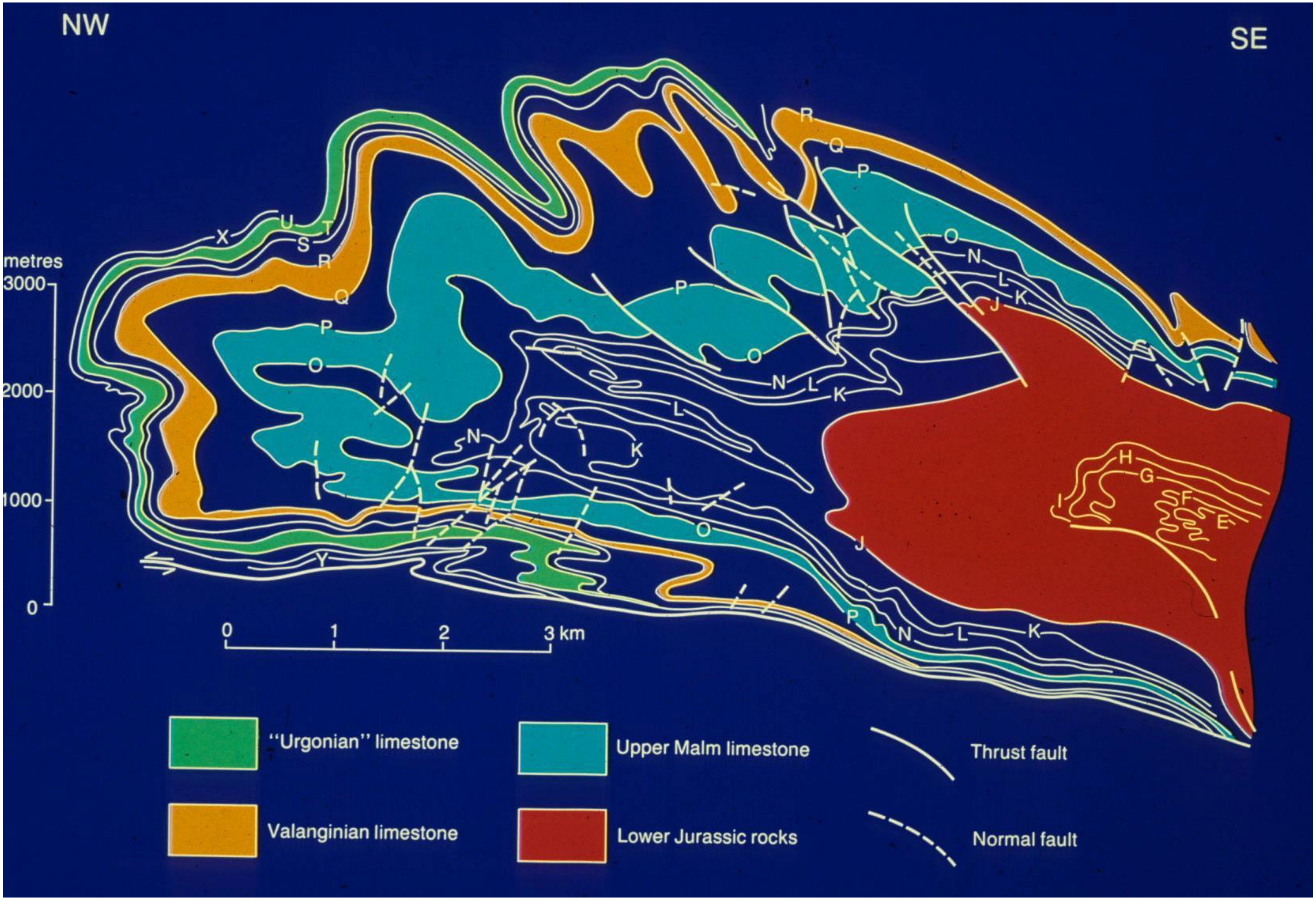

Figure 3. Down-plunge cross section of the Morcles Nappe (from Langenberg et al., 1987).

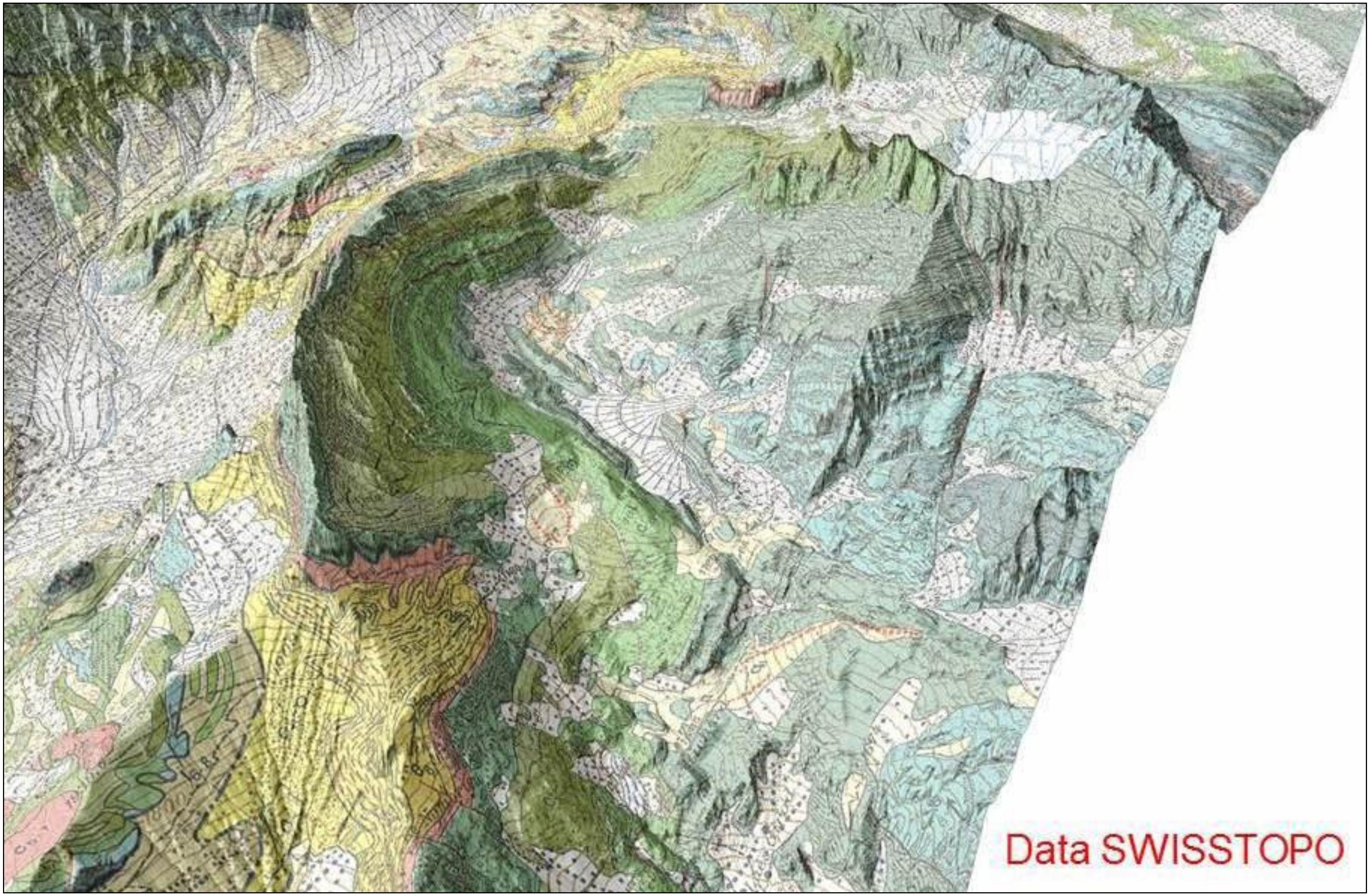

Figure 4. Geology of the Haute Pointe area draped over the LiDAR image of the Morcles area, viewed down-plunge.