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The 1879 geological map of Switzerland – Base map, georeference and evolution of geological signs

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Abstract: In the second part of the 19th century, a masterpiece of cartography was created: the Geological map of Switzerland. It made a standard of further geological mappings in Europe. The topographic basis was the 1:100,000 scale Dufour map (Dufourkarte) of the country. Therefore the georeferencing method is the same that of that base map. Here we provide the georeferencing method of the Dufourkarte and all constants need to be set in GIS environment to accomplish this work. Moreover, the geological mapping details are also shown, as the different date sheets of the map product show the effect of the Bologna color system, defined by the Second Geological Congress of Bologna in 1878. Making such a high-scale and detailed geological map and cross-sections, a possible basis of the recognition of the Alpian large folds (nappes), and even the early concept of plate of tectonics was provided. Interestingly enough, these forms were identified also in 1879 but accepted by the mainstream science only later, when the age of the Earth was supposed much closer to the present accepted figure.

The Dufourkarte and the geological map series

The cartographic history of each state highlights the first map that presents the country in some kind of unified system. Among these maps, the one that is already topographically accurate, with a survey method and scale that allows for cartographic support of both military and civilian purposes, plays an important role. In the case of Switzerland, this map is the 'Dufourkarte', a 1:100,000 scale map, compiled under the direction of General Guillaume Henri Dufour (1787-1875), published in 1845 (Graf, 1896). The Dufourkarte depicts the country in 25 sections, but the corner sections (sections I, V, XXI and XXV) either do not contain Swiss territory or are so small that they are depicted as a continuation of the map content of the adjacent section, with a slight interruption of the frame.

The significance of the Dufourkarte, in addition to and based on its topographic representation, is that it could be used as a working map, as a basis for the development of thematic maps to show the terrain. One of the most important of these is the series of geological maps presented in this work (Graf, 1896: 229-230). The source of the maps presented here is the Hungarian Geological Library (currently in the custody of the Regulated Activities Authority). 19 of the 25 sections are available (sections I, II, V, XX, XXI and XXV are missing, but this only indicates a Swiss territorial deficit for sections II and XX). Some of the map sections are also shown as duplicates. The first geological survey of circa 1870-1880 forms a complete series, supplemented by a second survey of circa 1900 for some sections and circa 1910 for others, especially near the French border. The names of the geologists who carried out the survey appear at the top of the frame of each sheet:

III: C. Moesch, U. Stutz, Vogelgesang

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IV: F. Schalch (Schaffhausen and Höhgau), A. Gutzwiller (most parts of the map), J. Schill (Ueberlingen)
VI: Aug. Jaccard
VII: J. B. Greppin (Jura), Bauchmann (plains)
VIII: C. Mösch, F. J. Kaufmann
IX: Arnold Escher, A. Gutzwiller
X: G. Theobald
XI: A. Jaccard (Swiss part), Marcel Bertrand (French part)
XII: V. Guilleron (western part), Aug. Jaccard (Neuenburg), J. Bachmann (eastern part)
XIII: F. J. Kaufmann (northern part), A. Baltzer (southern part), C. Moesch (central part)
XIV: A. Escher v. d. Linth, G. Theobald, A Baltzer, G. v. Fritsch, Albert Heim
XV: G. Theobald
XVI: Aug. Jaccard
XVII: M. G. Ischer, H. Gerlach
XVIII: Edm. von Fellenberg (northern part), J. Bachmann, C. Moesch (northwestern part), H. Gerlach (southern part)
XIX: Fr. Rolle
XXII, XXIII: H. Gerlach
XXIV: M. M. Spreafico, Negri (western part), M. Stoppani (eastern part)

The map frame has a double geographic coordinate system: the outer frame shows coordinates in grads (new degrees) and the inner frame shows coordinates in degrees, with longitudes in both cases with the Paris meridian. No projection coordinates or projection information are found in the frame. The main part of this first geological survey was made before the Bologna Congress of 1881 (Capellini, 1882), which standardized the geological color sign system, so the surface signs and coloring of the individual rock formations do not correspond to modern conventions (Fig. 1). The sheets which include the results of both the earlier and the post-1878 surveys not only show the improved geological resolution of the more detailed surveys, but also show the transition to the Bologna color system (Fig. 2).

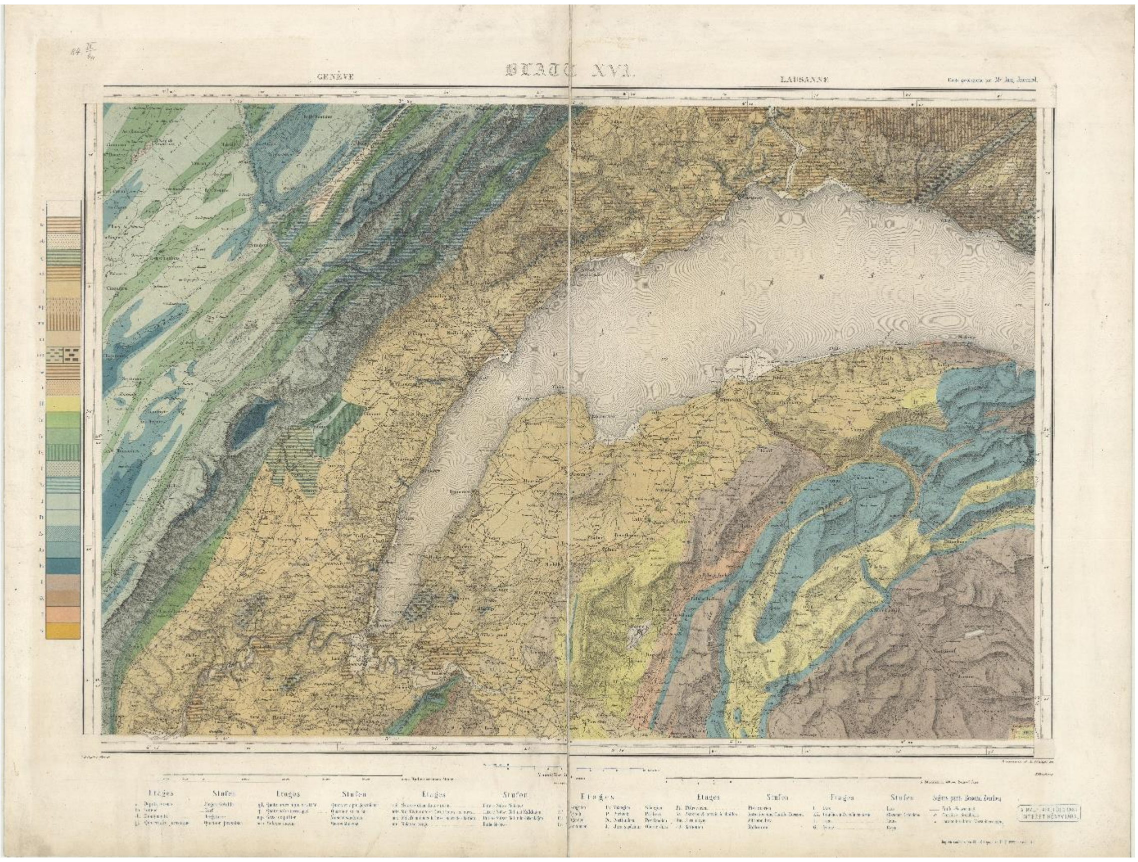


Figure 1: First geological survey of Sheet XVI (Geneva, 1883) with pre-Bologna color system

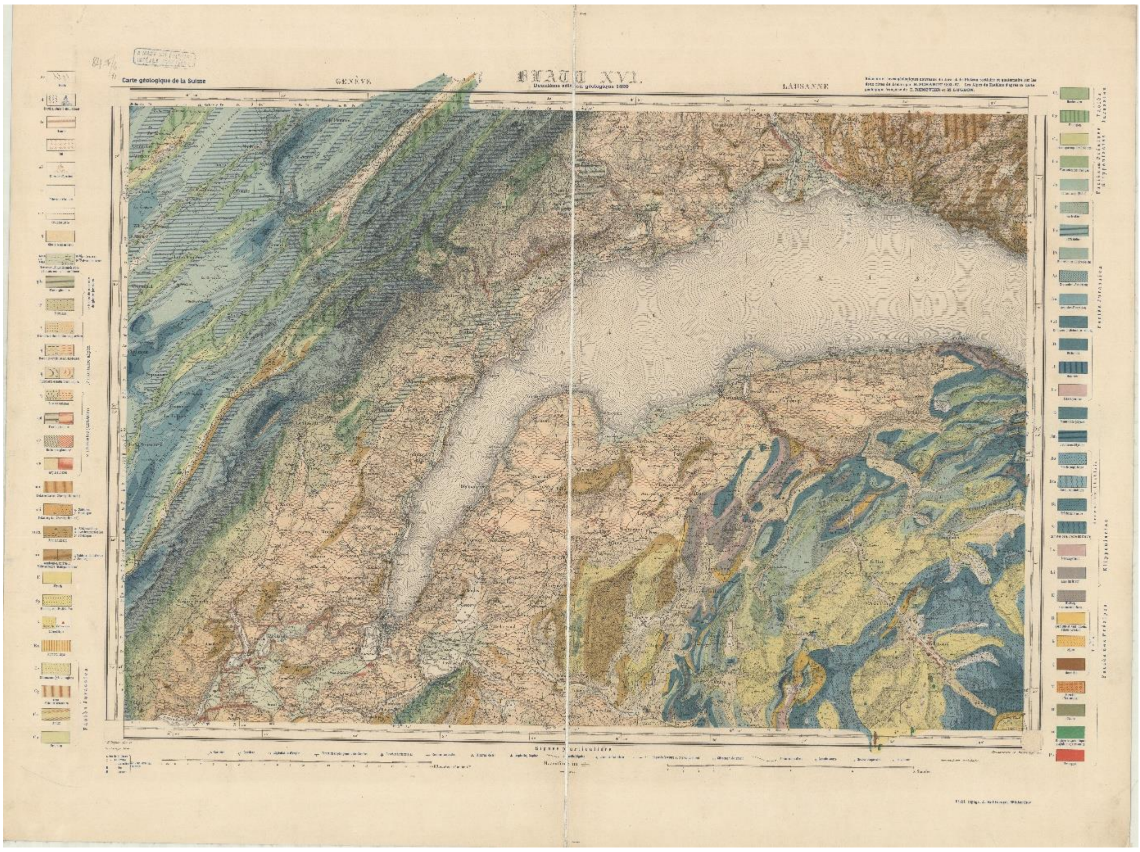
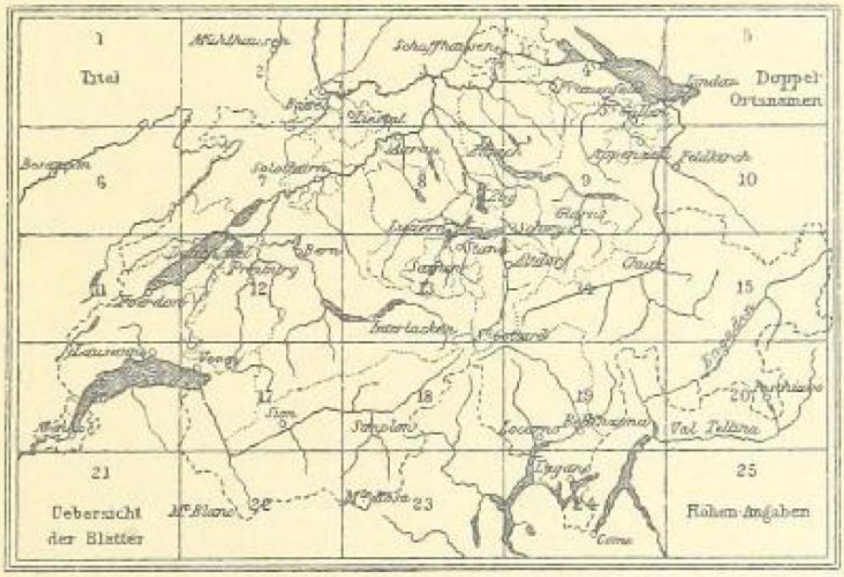


Figure 2: The second edition of Sheet XVI (1899) was not only based on a more detailed geological survey but also according to the Bologna color codes

Coordinate system and georeferencing of the maps under study

The projection of the map series is the modified Flamsteed, in modern terms, the Bonne projection (Graf, 1896: 76). The base surface is the Schmidt ellipsoid (semi-major axis 3,271,773 toise - converted to meters: 6,376,804 m; inverse flattening: 1/302.02; Graf, 1896: 75). The projection starting point was the old observatory in Bern (latitude = 46. 95167; longitude=7.44021 from Greenwich). It is no longer existing, but projecting its position onto Google Earth and reading it in WGS84, applying the geoid undulation value there, the geodetic datum is given by its abridging Molodensky's parameters as follows: dX=+1096 m; dY=+23 m; dZ=+676 m.
The physical size of the sheets is 70x48 cm, which at a scale of 1:100,000 gives a field extent of 70x48 kilometres (Figs. 3 & 4)


Die ganze Karte wird in 25 Blätter, jedes von $^{70}/_{48}$ cm, zerlegt, die in nachstehender Reihenfolge numeriert werden:

I	II	III	IV	V
IV	VII	VIII	IX	X
XI	XII	XIII	XIV	XV
XVI	XVII	XVIII	XIX	XX
XXI	XXII	XXIII	XXIV	XXV

Figure 3: The sheet numbering of the Dufourkarte, with the data describing the physical sheet size on top (Graf, 1896: 85).

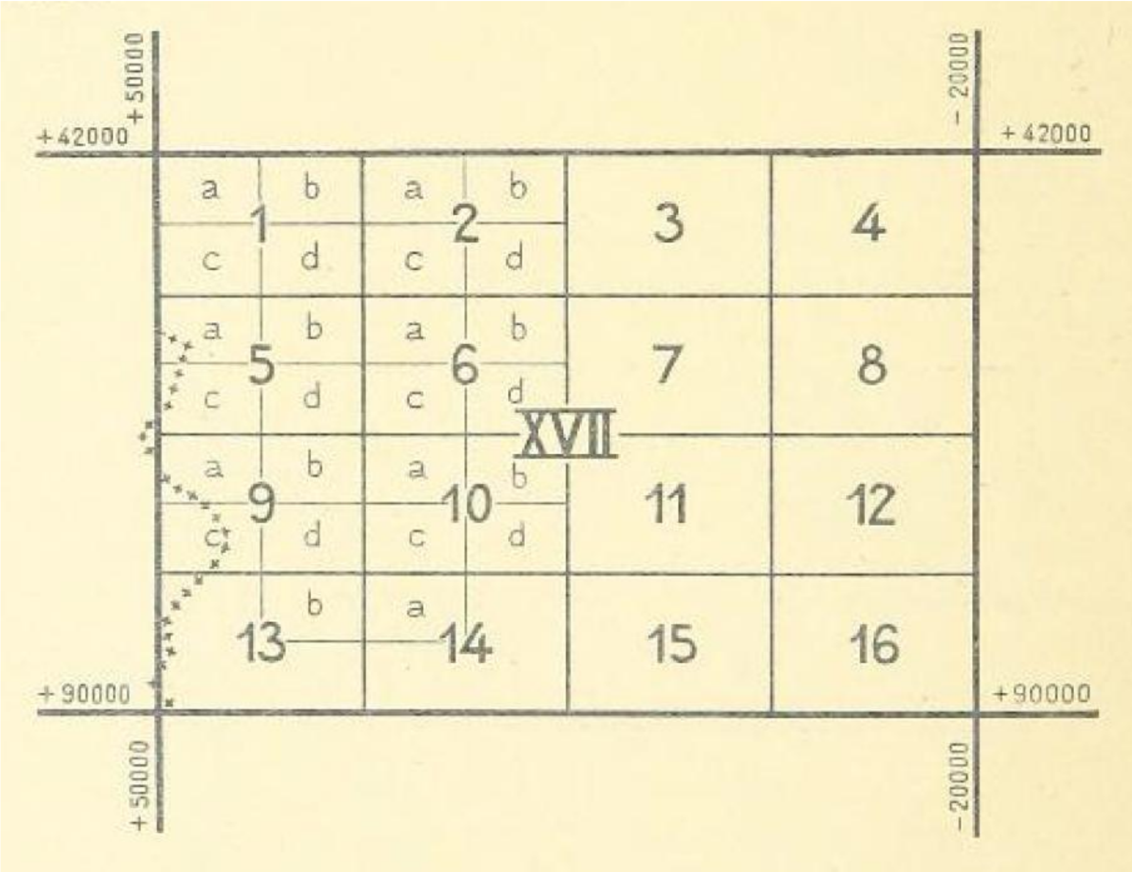


Figure 4: The coordinates of a 1:100,000 scale Dufour sheet in the coordinate system defined below (Graf, 1896: 86). The coordinates of the sheet boundaries in meters are prefixed here in the south-western orientation system; in our geospatial application, the prefixes must be reversed.

This information is now perfectly suitable for georeferencing the sheets of the Dufour map, thus the geological map series. For this purpose, a valid coordinate system specification in PROJ4 format (with a north-east orientation, i.e. by reversing the coordinate projections of the original map) is the following:

```
PROJCS["Bonne",
GEOGCS["GCS_BERN-DUFOUR",
DATUM["D_BERN-DUFOUR",
SPHEROID["Schmidt",6376804,302.0178080894222]],
TOWGS84[1096.0,23.0,676.0,0.0,0.0,-0.0,0.0]],
PRIMEM["Greenwich",0]
UNIT["Degree",0.017453292519943295]],
PROJECTION["Bonne"],
PARAMETER["central_meridian",7.44021],
PARAMETER["latitude_of_center",46.95167],
PARAMETER["false_easting",0],
PARAMETER["false_northing",0],
UNIT["Meter",1]]
```

During georeferencing, the corner points of the map sections are given in meters in this coordinate system (Fig. 5). The georeferenced mosaic fits the terrain with a very good accuracy both in

OpenStreetMap and after a KMZ export in Google Earth, the latter also allowing a three-dimensional display of geological observations.

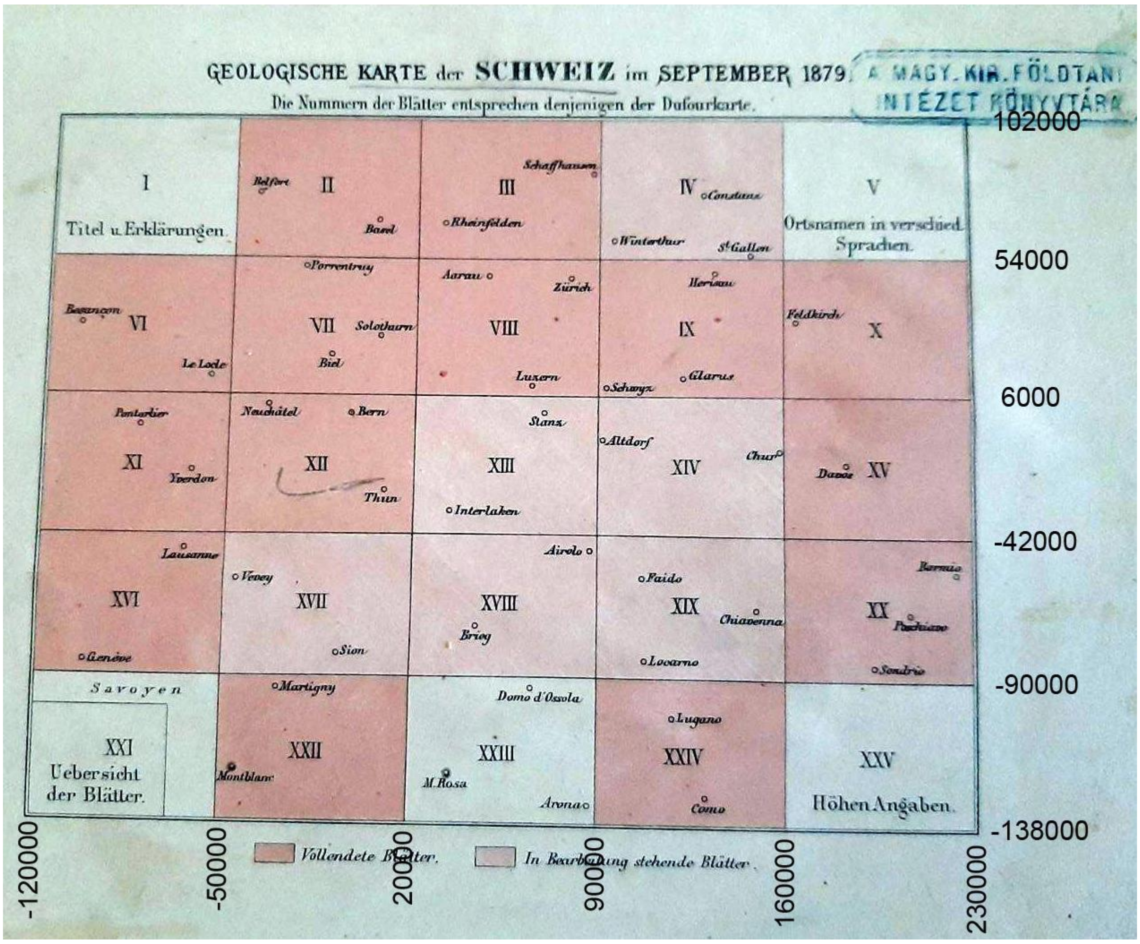


Figure 5: The overview map of the Dufour series with the Bonne-projected coordinates of the sheet boundaries

The importance of maps in the recognition of Alpine geological structures

Much of the mass of the Alps was uplifted during the collision of the African (Apulia, Adriatic) and Eurasian plates, and much of the sedimentary rocks that were exposed were deposited at the bottom of the Tethys Ocean, which had previously laid between the two converging plates. Some of the sedimentary layers were pushed over each other in wide nappes of more than 100 kilometers in size as the plates collided, and deep valleys were cut into them by subsequent fluvial and glacial erosion. The idea of nappe systems had been raised before, but it was in fact exactly during the discussed geological mapping that it became clear that the structural features already recognized in situ were typical of much of the Swiss Alps. The first recognition of mobile structures in the Alps was made precisely by the geologists involved in the survey (cf. Trümpi, 2001, and Letsch, 2014). Arnold Escher (1845) and Albert Heim (1871), working together on Section XIV, the most geologically complex central part of Switzerland, were the two most prominent ones to propose an explanation of the structure in the Glarus area as a 'double fold' (Figs. 6, 7 & 8). This was in fact the first step towards the Alpine acceptance of mobile geological structures, in fact nappe structures of the size given above, by Suess (1909), at a time when the age of the Earth, prior to radiometric dating, was assumed to be an order of magnitude less than it is today.

Figure 6: Recognize the folding structures on the sections, appended to the geological map series.

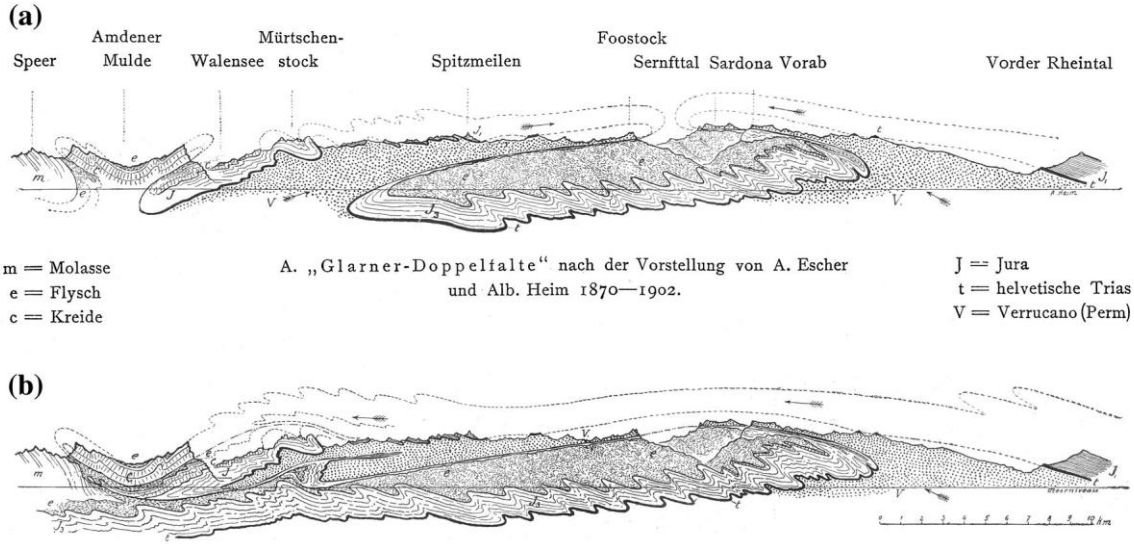


Figure 7: Two different structural geological interpretations of the section in the southeastern foothills of Glarus: the Heim (1871) explanation of "double fold" at the top and the regional nappe model (Letsch, 2014: 66) at the bottom.

Figure 8: The section, shown in previous figure, in a 3D-shown, georeferred map mosaic (red line).

Conclusions

The base map of the 1879 geological map of Switzerland was the Dufourkarte. It can be georeferenced by these metadata: projection: Bonne, with the center at the Old Bern Observatory (central meridian is 7.44021 degrees from Greenwich, latitude of center is 46.95167 degrees – the observatory is not existing anymore, this location is at the central campus of the Bern University). The datum is using the Schmidt ellipsoid (a=6377804 m; 1/f=302.0178081) and its location parameters are: dX=+1096 m; dY= 23 m; dZ= 676 m. The Old Observatory is depicted in Sheet XII. The northern boundary of Sheet VII is N=+6000 m; so the southern edge follows the line of N=-42000 m. Western edge is E=-50000 m while the eastern one is E=+20000 m; thus the extent is indeed 70 x 42 kilometers. From this sheet, the system can be easily coordinated and georeferenced, using just the sheet corner points.

As all the spatial data were available when the map and sections were drawn, the geologists who produced them recognized the Alpine nappe structures. However, the accepted views of the time about the age of the Earth precluded them from interpreting them correctly. For this reason, interesting alternatives to the current interpretation of the nappes were presented - and this prevented plate tectonics theory from being developed in relation to the Alps as early as the late 19th century.

References

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