A NEW DATABASE OF ALPINE ROCK FALLS AND ROCK AVALANCHES

Philippe Schoeneich[1], Didier Hantz[2], Philip Deline[3], François Amelot[4], and *Rockslidetec-Action A* project partners

ABSTRACT

A new database of Alpine rock falls and rock avalanches has been established, based on the compilation and verification of published inventories, and on additional cases documented by project partners. All data are integrated in a database, with two information levels: basic data for all cases, detailed data for selected cases. The database contains by now around 550 cases, among them round 360 true rock fall and rock avalanche events. The detailed data will serve to various statistical analysis of susceptibility factors, frequency, etc. and for detailed case studies.

Keywords: rock falls, rock avalanches, Alpine inventory, database

CONTEXT AND GOAL OF THE DATABASE

The InterregIIIa *Rockslidetec* project (2003-2006) was designed in order to develop new tools for the detection and the propagation modelling of rock avalanches (Rockslidetec final report). Within this project, a new database of Alpine rock falls and rock avalanches has been established (*Action A* of the project), with two main goals:

- on short term, provide the experts with a wide set of information allowing an improvement of their analyses based on analogies with known cases. This aspect can be extended to the monitored unstable sites;
- on longer term, set the basis for an advanced statistical analysis of the phenomenon (frequency/probability, susceptibility, triggering and propagation factors).

The database focuses on very rapid to extremely rapid rock movements in the sense of the international classification by Cruden & Varnes (1996), which include: rock falls, very/extremely rapid rock slides, and rock avalanches. For simplification we will use rock fall as generic term.

The database contains two information levels, using the same database structure:

- a comprehensive inventory of events of more than 10^6 m^3, covering the whole Alpine range. The threshold of 10^6 m^3 has been considered as a realistic goal to achieve exhaustivity over the entire Alps. At this information level, only limited data are collected like name(s), location, date, type and if possible area and volume, mostly from literature;
- a detailed database, containing also smaller events, and covering mainly the working areas of the project partners (Valais, Aosta valley and Northern French Alps). These data have been collected by field work.

[1] Institut de Géographie Alpine, Université de Grenoble, 14 bis av. Marie-Reynoard, F-38100 Grenoble. PACTE UMR 5194 CNRS. Philippe.Schoeneich@ujf-grenoble.fr, fax: ++33 4 76 82 20 01
[2] Université de Grenoble, Laboratoire de Géophysique Interne et Tectonophysique, CNRS, Observatoire. Didier.Hantz@ujf-grenoble.fr
[3] Université de Savoie, EDYTEM, UMR 5204 CNRS. pdeli@univ-savoie.fr
[4] Centre de la Nature Montagnarde, Sallanches. f.amelot@centrenaturemontagnarde.org

DATABASE STRUCTURE

The database is designed to allow detailed analysis of susceptibility, triggering and propagation parameters. It contains therefore 38 tables including 305 fields organized in six main domains:

- topographical and geological characteristics of the concerned valley slopes;
- initial profile of the slope;
- post-failure profile of the slope;
- characteristics of the failure, including jointing, triggering factors, …
- characteristics of the deposit;
- references to documents, literature, including reference numbers in the previous published inventories.

All data are organized around the table *Rockfall*, which contains the identification and the general caracteristics of the event. Fig. 1 gives the basic structure of the database. Fig. 2 shows an example of the user interface for a detailed case.

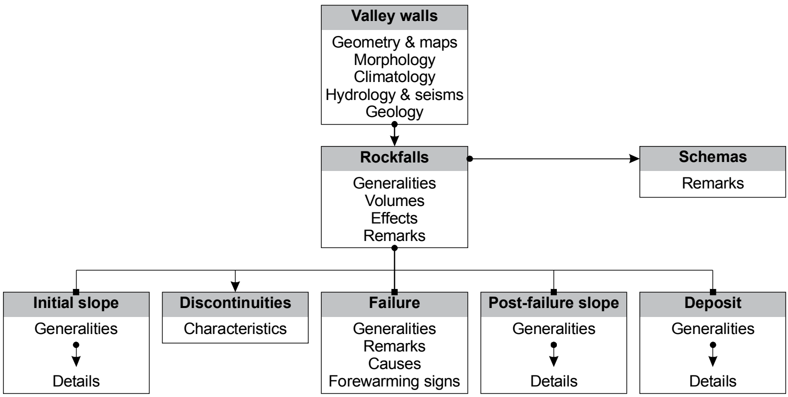


Fig. 1 Overall database structure

The "valley wall" is a relatively homogeneous area from a geological and geomorphological point of view. It extents transversely from the valley bottom to the top of the valley slope, and longitudinally as far as the geological and morphological characteristics remain roughly constant. It makes it possible to calculate a spatial and temporal rock fall density, if a sufficient number of rock falls have occurred in the same valley wall or in valley walls with the same geological and geomorphological characteristics. The rock fall densities for different geological and geomorphological contexts could then be compared (Dussauge-Peisser et al., 2002).

The initial and post-failure slopes are described, as well as the characteristics (attitude, spacing, extension, roughness, filling) and the role of the main discontinuity sets. They are subdivided in slope segments. This description can help the expert to determine the volume, geometry and failure mechanism of a potential failure in similar conditions. Information on the triggering factors makes it possible to know what type of triggering factor is the most efficient according to the geological and geomorphological context, and to the potential failure mechanism.

Information on the propagation includes geometrical parameters on the propagation path. It can be used for a better knowledge of the propagation angle (*Fahrböschung*) according to the geological and geomorphological context, and to the potential failure mechanism.

The description of the deposit includes geometry, geomorphological and granulometrical observations. The description can be subdivided in sub-areas with homogeneous characteristics, in order to account for the complex shape of many deposits. These data serve to interpret the propagation patterns, and to control modeling results. Figures (maps, topographical/geological profiles, photographs, ...) can be added to illustrate any of the described parameters.

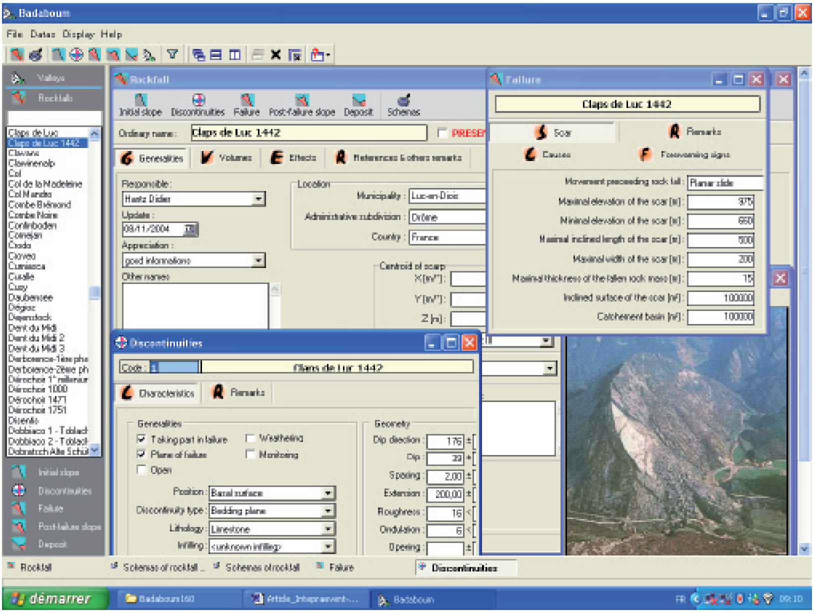


Fig. 2 User interface, illustrated with the Claps de Luc 1442 AD rockslide.

The database has been developed on MS Access 2000, using MS JetEngine 4.0 and the object interface MS-DAO 3.6. The user interface has been developed with Delphi 7 (fig. 2). The database can be used on any Windows computer without having Access installed. This version has been distributed to project partners only. A new, web interfaced version, is under development and will allow on-line access. The database will be available online in 2008 on the site www.CREALP.ch.

The same database structure has been used both for the inventory and for the detailed cases. For the inventory, only the available fields are documented. The detailed database needed additional field work and document analysis, which has been done by the project partners from 2003 to 2006.

THE INVENTORY DATA

The inventory is mainly based on the compilation of existing published inventories (Montandon 1933, Strele 1936, Abele 1974, Eisbacher & Clague 1984) and other literature sources (Erisman & Abele 2001, Heim 1932, Oberholzer 1900, 1942, Schindler 2004, ...), as well as the *Infoslide* database of the Swiss geological survey. These inventories consider events of more than 1 to 3 10^6 m^3, as well as smaller events that caused numerous victims or significant damage. The inventories of Montandon (1933), Strele (1936) and Eisbacher & Clague (1984) are restricted to historical cases. Abele (1974) includes cases known from geological and geomorphological survey. Although there title announces inventories of “éboulements” or “Bergstürze”, most of them include also mass movement events of other types, like debris flows, slides or even glacial lake outbursts, as well as events where the main process is unknown or uncertain. Except *Infoslide*, none of these inventories was available in numeric form, and they had never been put together.

In order to harmonize the dataset and to allow the selection of true rock falls and rock avalanches, the following work has been done:

- extraction of text data and tables and conversion into tabular datasets;
- comparison of the inventories, identification of corresponding cases and elimination of duplicate records;
- separation of distinct events: some inventories agglomerate in a same case several successive events on the same location, or even different events in the same area. These have been considered as distinct events;
- identification of the main process for all events. Non-rockfall cases have been maintained in the database, in order to keep the integral original datasets, except for the *Infoslide* database, where only the rock fall/rock avalanche cases have been considered;
- determination of geographic coordinates for all cases (center point of scar or deposit), and conversion of the various national coordinates, if available, in universal WGS 84 geographic coordinates.

The following data fields could in most cases be filled:

- current name of event, and other corresponding names used by various authors;
- date of event for historical events, dating if available for dated events;
- WGS 84 geographic coordinates of center point (scar or deposit), if available: national metric coordinates;
- administrative subdivision at country and canton/department/Land level, if available at community level;
- main propagation process;
- number of victims, level and type of damage;
- if available: surface of deposit, volume, and other tabular data (like height, length, H/L or *Fahrböschung*, mainly from Abele 1974 and Erisman & Abele 2001);
- triggering factor if known;
- identification number in the published inventories and literature sources.

Published figures have been scanned and included, as well as in some cases map extracts for location and delimitation and, if the site could be visited, photographs.

In addition to the published sources, several tens of new cases, resulting from personal surveys of the project partners have been added. This results in a total of 554 events (500 from published inventories and 54 new cases from project partners, status September 2006), among them 360 are very rapid to extremely rapid rock movements, the others being either uncertain or of other types (table 1 and fig. 3). Several events involve process chains, like rock falls in catchment basins reworked by subsequent debris flows.

Tab. 1: Number of events recorded in the database

Source	**Nb of entries**	**Effective nb of events**	**Nb of rockfall events**	**Nb of events of uncertain type**	**Nb of non-rockfall events**
Montandon 1933	160	164	103	1	60
Strele 1936	35	35	2		33
Abele 1974	279	285	220	53	12
Eisbacher & Clague 1984	137	216	107		109
New cases	54	54	54		
Total (excl. duplicates)		554	360	54	140

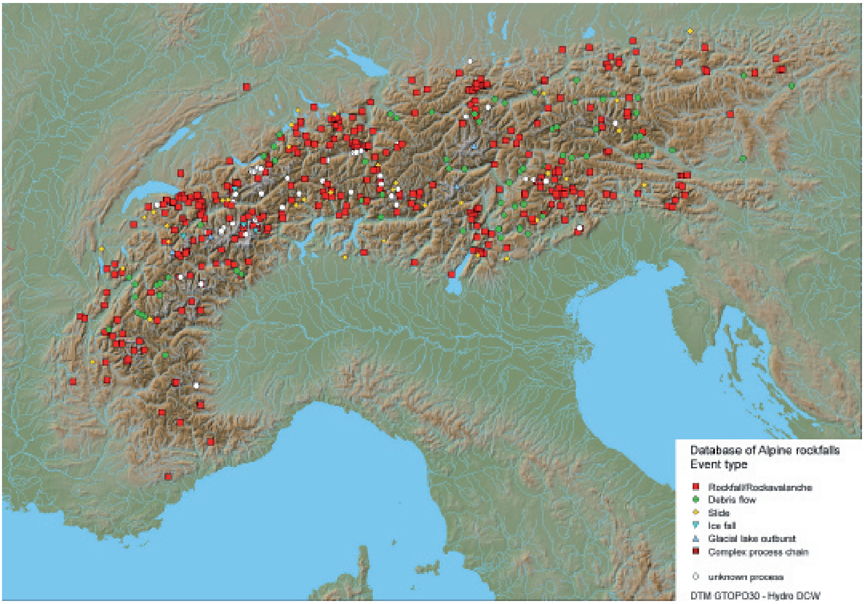


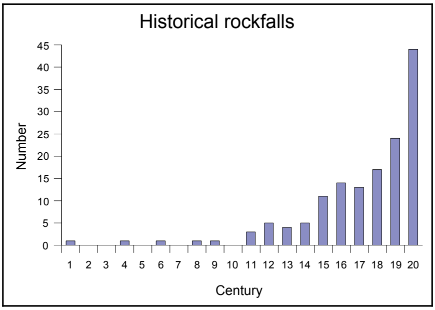
Fig. 3: Location map of all documented cases. Non-rock movements mentioned in published inventories have been kept in the database, in order to allow the reconstruction of these inventories.

This inventory allows already some considerations on the spatial distribution of the cases, or on the temporal distribution of historical records. Fig 3 shows the distribution of the documented cases. It appears that the highest density is encountered in the Swiss Alps, followed by the Western Austrian Alps and Northern Italy, where the previous authors concentrated their work. The Southern Alps, both on the French and particularly the Italian side, as well as Eastern Austria and Eastern Slovenia show a very low density of recorded events. The circa 50 cases added by project partners concentrate in their working areas (Valais, Aosta valley and Rhone-Alpes region) and are not represented on the map.

Among the 357 certain rock falls or rock avalanches, 160 are dated: most are historical events, 15 are Holocene events dated by radiocarbon or radionuclides. A few Lateglacial events are indirectly dated by associated moraines. The distribution of historical events shows that their frequency is dependent on the quality of the historical record (fig. 4). Four periods can be distinguished:

- the Antiquity and early Middle Ages, with isolated records only, almost restricted to cases that caused very numerous victims, and/or triggered by earthquakes;
- the end of Middle Ages (11th to 14th centuries) with 3 recorded cases/century;
- early modern time (15th to 18th centuries) marked by more systematic archives;
- the two last centuries, marked by the beginning of the scientific interest for natural processes, and later by systematic inventories.

Within each period, the frequency seems to be homogeneous, but the density of the record improves for younger periods. This expected result confirms that there are many missing cases, and that a statistical exploitation of the frequency with time would give no reliable results.



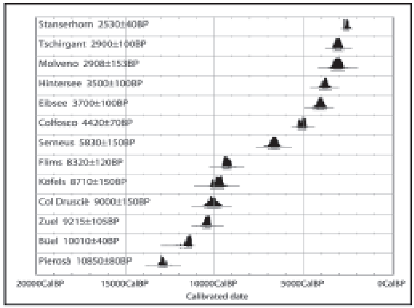


Fig. 4 Distribution of 145 recorded historical rock fall events (number of events/century)
Fig. 5 Distribution of calibration ranges of 13 radiocarbon dated rock fall events

The few dated Holocene events are equally distributed over the Holocene, but their number is insufficient to allow any conclusions on a possible influence of climate changes (fig. 5). One can notice however that several events, including the two largest known (Flims and Köfels), occurred at the beginning of the Holocene Climate Optimum, a period during which almost no slide event is dated (Schoeneich et Dapples 2004). This could indicate that large rock falls/rock avalanches are less dependent on precipitation than other types of mass movements.

Concerning triggering factors, the trigger by earthquake, often mentionned as possible or probable trigger, is actually confirmed for only 8 historical events. It must however be pointed out that the trigger is unknown in most cases.

THE DETAILED CASES

Several tens of events have been documented in detail, ranging in volume from 10^4 m^3 to several 10^6 m^3. Most cases are located in the working area of the project partners. They include cases known from the inventory, which have been revisited in order to acquire detailed data, and new cases studied by the project partners. Several cases of unstable zones representing potential hazards have been documented too.

The acquisition of detailed data needed intensive field work, including survey of the deposit and of the scar, measurements of the jointing in the scar area, as well as analysis of available documents like pre-failure topographical data.

This information level is not intended to cover exhaustively the entire Alps, but to focus on the most important, respectively the best documented events, and on some study areas. In some limited and geologically homogeneous areas, like the Ecrins massive or the Chartreuse range in France, a comprehensive inventory covering the whole size range will be achieved, in order to allow frequency/size analyses (Dussauge-Peisser et al., 2002).

In most cases, only part of the fields could be documented. The dataset is therefore very heterogenous yet, making statistics difficult at the present state. As examples of good documented fields, volume estimations for the scar or the deposit are available in 156 cases (fig. 6), the area of the deposit in 285 cases, values for the *Fahrböschung* (or H/L) for 216 cases. But initial slopes are documented in only 27 cases, geometric characteristics of the scar in 38 cases, discontinuities have been measured for only 30 cases.

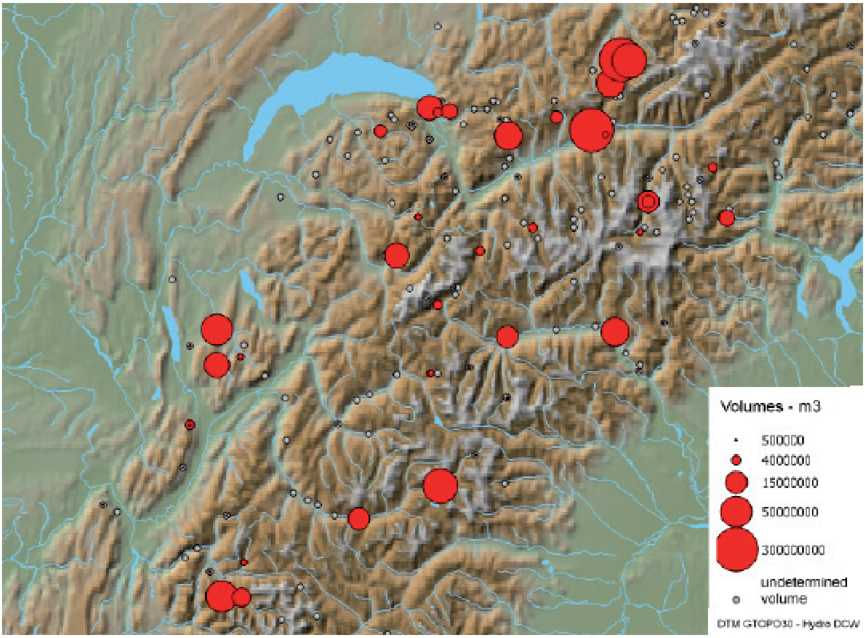


Fig. 6 Volume of rockfall events within the working area of the project partners.

OUTLOOK

The database structure is ready and tested, but the data collection is still in progress. It will be continued within the InterregIIIb project *ClimChAlp*, in order both to complete and improve the inventory and to extend the detailed database to the entire Alps for the largest rock fall and rock avalanches, together with new partners from Germany, Austria, Italy and Slovenia.

As mentioned above, it should be made available on-line, for consultation and for on-line contribution on the website www.CREALP.ch. It should also be linked to a GIS, in order to allow mapping and spatial analysis.

The collected data will be used in future for:
- search for similar cases in hazard assessment;
- statistical analyses of susceptibility and triggering factors (Frayssines et al., 2006);
- frequency analyses, giving constraints to hazard assessment (Hantz et al., 2003);
- study of the influence of climate changes on the occurrence of rock avalanches during the Holocene period (Schoeneich et Dapples 2004);
- analysis of propagation;
- ...

In the idea of the Rockslidetec project, the dataset should also serve as base and control data for the validation of propagation modelling. It appeared however that only a limited number of recent events, for which detailed topographic data of the pre-failure slope are available, are usable.

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