Volume n° 5 - from P37 to P54

32nd INTERNATIONAL GEOLOGICAL CONGRESS

INSTRUMENTED EXPERIMENTAL SITES FOR THE CONTROL OF LANDSLIDE HAZARDS IN MOUNTAIN ENVIRONMENTS: THE GERMANASCA AND SUSA VALLEYS (NORTHWESTERN ITALY)

Leader: G. Lollino

Associate Leaders: M.Giardino, P. Allasia, M. Baldo, D. Giordan

Post-Congress **P41**

Field Trip Guide Book - P41

Florence - Italy
August 20-28, 2004

The scientific content of this guide is under the total responsibility of the Authors

Published by:
APAT – Italian Agency for the Environmental Protection and Technical Services - Via Vitaliano Brancati, 48 - 00144 Roma - Italy

APAT
Italian Agency for Environment
Protection and Technical Services

Series Editors:
Luca Guerrieri, Irene Rischia and Leonello Serva (APAT, Roma)

English Desk-copy Editors:
Paul Mazza (Università di Firenze), Jessica Ann Thonn (Università di Firenze), Nathalie Marléne Adams (Università di Firenze), Miriam Friedman (Università di Firenze), Kate Eadie (Freelance indipendent professional)

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Acknowledgments:
The 32nd IGC Organizing Committee is grateful to Roberto Pompili and Elisa Brustia (APAT, Roma) for their collaboration in editing.

Graphic project:
Full snc - Firenze

Layout and press:
Lito Terrazzi srl - Firenze

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AUTHORS:
P. Allasia[1], C. Audisio[1], M. Baldo[1], C.G. Cirio[1], G. Lollino[1], D. Giordan[1], F. Godone[1], G. Nigrelli[1], F. Alpe[2], S. Ambrogio[2], M. Giardino[2], L. Perotti[2], L. Sambuelli[3], G. De Renzo[4], D. Fontan[5], T. Barbero[6]

[1] *CNR - IRPI, Sezione di Torino - Italy*
[2] *Università di Torino - Italy*
[3] *Politecnico di Torino - Italy*
[4] *Provincia di Torino - Servizio difesa del suolo - Italy*
[5] *SEA Consulting, Torino - Italy*
[6] *Consultant Geologist, Rivoli (To) - Italy*

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P41

Front Cover:
La Ayas landslide (Bardonecchia, Susa Valley)

Leader: G. Lollino

Introduction

Lollino G., Giardino M.

Site investigation, testing and monitoring are vital to the practice of Engineering Geology and Geotechnical Engineering, in contrast to the practice of most other branches of Engineering in which people have greater control over the materials with which they deal. Use of site investigation, in situ testing, and field instrumentation and monitoring requires a detailed conception of the variations that may be expected in the natural or artificial deposits in which the observations are to be made and a clear conception of the way in which the observations are to be obtained, recorded, digested, and used on the particular project for which the design is being prepared.

Given this understanding it is not surprising that site investigation, testing and monitoring are rapidly becoming the focus of major scientific research, engineering study and practices throughout the world.

This field trip will be carried out in two alpine catchments (Chisone-Germanasca and Susa Valleys, North-Western Italian Alps) affected by different types of landslides (rotational and translational slides, rock falls, deep-seated gravitational slope deformations) and by snow avalanches.

In the studied areas several remote sensing and field recognition techniques have been tested. Furthermore, on the unstable sites different monitoring networks have been established, such as a Topographic Total Station, an Automated Inclinometric System, and a Geographic Positioning System network, a piezometric network, a microseismic network and wire extensometers. All these systems are remotely controlled. The interest of the local community in monitoring these areas is related to the fact that landslides and avalanches threaten many villages, as well as important lifelines along the Italy-France border area (Susa Valley) as for example the only existing road that lead to skiing resorts of great interest for the Winter Olympic Games of Turin 2006 and also to some active talc quarries (Chisone and Germanasca valleys).

Logistical background

At the arrival in the Turin area (Sunday, August 29th 2004) the field trip will approach the internal (italian) side of the NW-Alps at the mouth of the Chisone valley, near Pinerolo. The field-trip topics will be introduced by a general presentation of the program and an overview to the geological and geomorphological characteristic of the central part of the Western Alps. A touristic visit to the Fenestrelle Fortification will follow.

On Monday, the instrumented sites for monitoring landslides and avalanches of the Germanasca Valley will be visited. An historical talc quarry, no longer active but being reclaimed for tourist purposes, will be also visited as a look at past working techniques and at the old miners' lifestyle. In the evening a traditional and classic music show will be offered, performed in the Fenestrelle Fortification.

After a short visit to the Sestriere Olympic site (Sestriere, 2050 m a.s.l.) and a stop at the Cesana educational site for environmental resources and natural hazards, the last day will be devoted to the general overview on large-slope instabilities along the Susa Valley and to the in situ analysis of monitored landslides (Sauze d'Oulx "paleolandslide"; Cassas landslide). An audiovisual presentation on new techniques for slope instabilities recognition and monitoring will be offered, with distribution of geological maps and didactic booklets on geology of the Western Alps. The visit will finish at the Exilles Savoy Fortress, viewpoint over Clot Brun large-slope instability.

During the Field Trip, dinners and overnight stays wiil be offered at the Nasi Hotel of the "Consorzio Pra Catinat" Environmental Centre. It can be reached from the km 68 of SS 23 (at "Depot") turning right along the "Colle delle Finestre" road ("SP 172") up to the "Consorzio Pracatinat's" buildings, located at an elevation of 1650 m a.s.l. Since 1987 the Environmental Centre is specialized in educational projects and researches for students and teachers, devoted to the environmental resources and the sustainable development.

Field references

The essential general landscape information about the field trip area can be obtained by the geographic maps of Italian Military Geographic Institut (IGM), map of Italy 1:100.000 in scale, sheet numbers: 54 – Susa, 55 – Bardonecchia, 66 – Cesana Torinese, 67 – Pinerolo. The local maps are available from the Technical Services of the Piemonte Region, CTR 1:10.000 in scale, numbers: 153, 154, 155, 171, 172, 173.

The more recent geological cartography regarding the study territory is constituted by Maps 132-152-153 "Bardonecchia " and 154 "Susa" of the Geologic Map of Italy, scale 1:50.000. The Map "Bardonecchia " covers the Central and Upper Susa Valley and a limited portion of the Upper Chisone Valley. The Map

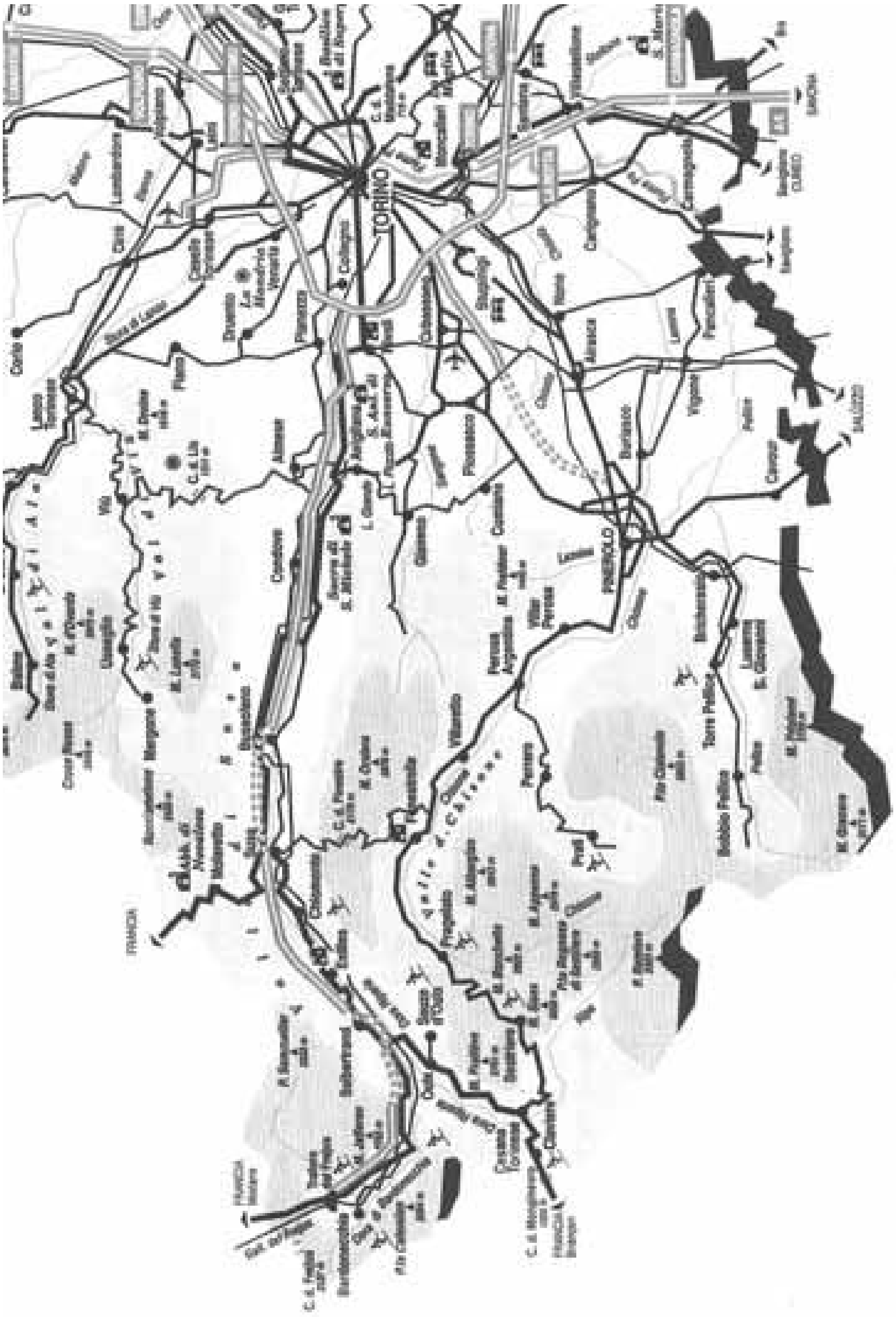

Figure 1 - Road map of the western part of Torino Province.

"Susa" contains the Lower Susa Valley and a part of the Middle Chisone Valley. For the Lower Chisone Valley, the only complete cartographic representation of the zone is Map 67 "Pinerolo" pertaining to the Geological Map of Italy scale 1:100.000, elaborated from 1890 to 1910.
The Upper Susa and Chisone Valley, (comprising Thuras Valley, Ripa Valley, Colle del Sestriere and Troncea Valley) are included in Map 66 "Cesana Torinese" from the Geologic Map of Italy, scale 1: 100.000, whose last reviews correspond to 1910-1911. Currently this area is still under survey for a new map of the Geologic Map of Italy, scale 1:50.000

Climatic Framework

Nigrelli G.

The Piemonte region is characterised by in what is normally defined as a "humid continental climate". In Europe this type of climate extends from latitude 45° to 60° N. When the polar and tropical air masses meet there are strong thermal seasonal contrasts and the weather is very variable each day. Particularly, in our region there is a "moderate transition climate", that is, a climate between a sub-polar cold, the Mediterranean hot and, longitudinally, between the western maritime humid and the eastern continental dry or peri-desertic. The atmospheric instability and the particular geomorphological conformation of the territory determine a pronounced seasonal variability with marked thermal excursions, different amounts of rain from zone to zone, and different annual rain distribution. It's maximum corresponds with spring and autumn.

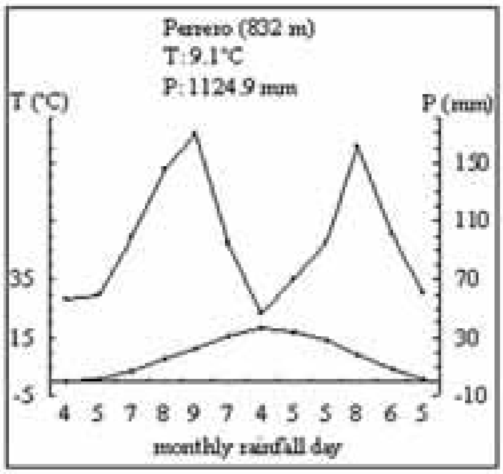

Figure 2 - Perrero station shade-thermal diagram.

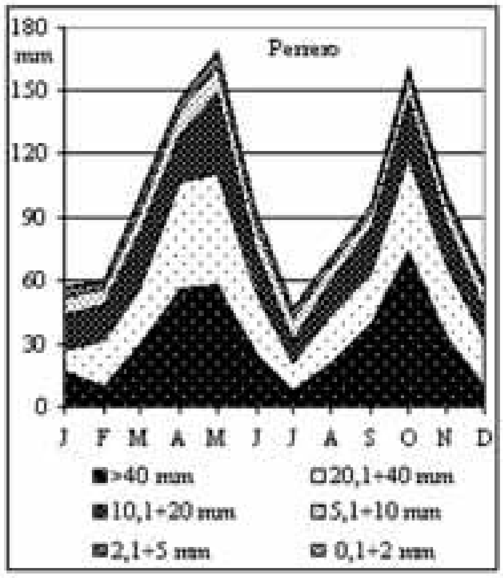

Figure 3 - Fragmentation of the average monthly precipitations based on daily intensity.

The "alpine region climate" (above 1000 m) is interested by a series of Atlantic, Gulf of Genova and Mediterranean depressions in autumn, winter and spring. Stabile periods characterize the winter, when the region is under the influence of the center-European anticyclon. During the summer the Azzorre anticyclon attenuates the air circulation favoring, thanks to ground heating, the formation of diurnal cumulus clouds, with the possibility of intense showers and storms.
Val Germanasca has a Pre-alpine rain regime (Figure 2), with the main minimum in winter, maximum in spring and secondary in autumn. The average monthly temperatures vary from -0.1°C in January to 18.0°C in August. The average annual days of frost is 92. It's never possible to have P<2T.
Spring and autumn correspond with the two most important rain periods and, of course, the most critical and dangerous for river, torrential and slope phenomena due to meteoric water (Figure 3). In Autumn it's more likely to have these events, since it's characterized by the most elevated precipitation density. The maximum precipitations for consecutive days don't overpass more than 5-6 days and this event always manifests in a similar way. First it's possible to have 1 or 2 days of light and sporadic water precipitations. Subsequently a second phase, the most important and dangerous, of 3 days, in which rain is incessant and

intense. The third and final phase, can last up to 3 days, in which the event exhausts itself according to different forms.

Regional geological setting

Cadoppi P., Giardino M.

The field trip area (figure 4) is located in the central part of the Western Alps. The Chisone and Susa Valleys cut through the alpine chain showing well-famous geological sections of the internal side of the alpine structure.

The Western Alps represent the axial zone of the Alpine Chain where is recognizable an imbricated stack of continental crust and oceanic units. They are the result of a complex geodynamic process: after a lithospheric oceanic subduction, a continental collision occurred between the European and Insubric ("Adria") paleocontinents (Polino et alii, 1990).

From the top to the bottom of the structure and from the inside towards the European foreland, historically in the alpine chain four main structural domains have been recognized (Polino et alii, 2002):

- the "South-Alpine domain", a portion of the Insubric margin showing internal vergence and lacking in alpine metamorphism. It is separated by the external domains through the Insubric line.
- the "Austro-Alpine domain", a structurally elevated complex in the alpine building, correlated to the South-Alpine domain.
- the "Penninic domain" multilayer complex with preserved mesozoic oceanic crust units and several continental crust sheets and related Mesozoic covers, which record and well preserve the alpine tectonometamorphic evolution.
- the "Helvetic-Dauphinois domain", the most external structural element of the chain, which represents the European foreland portion involved in the alpine orogenesis. It is separated by the inner domains by the Pennidic front. As in the South-Alpine Domain, the Helvetic-Dauphinois domain wasn't deeply affected

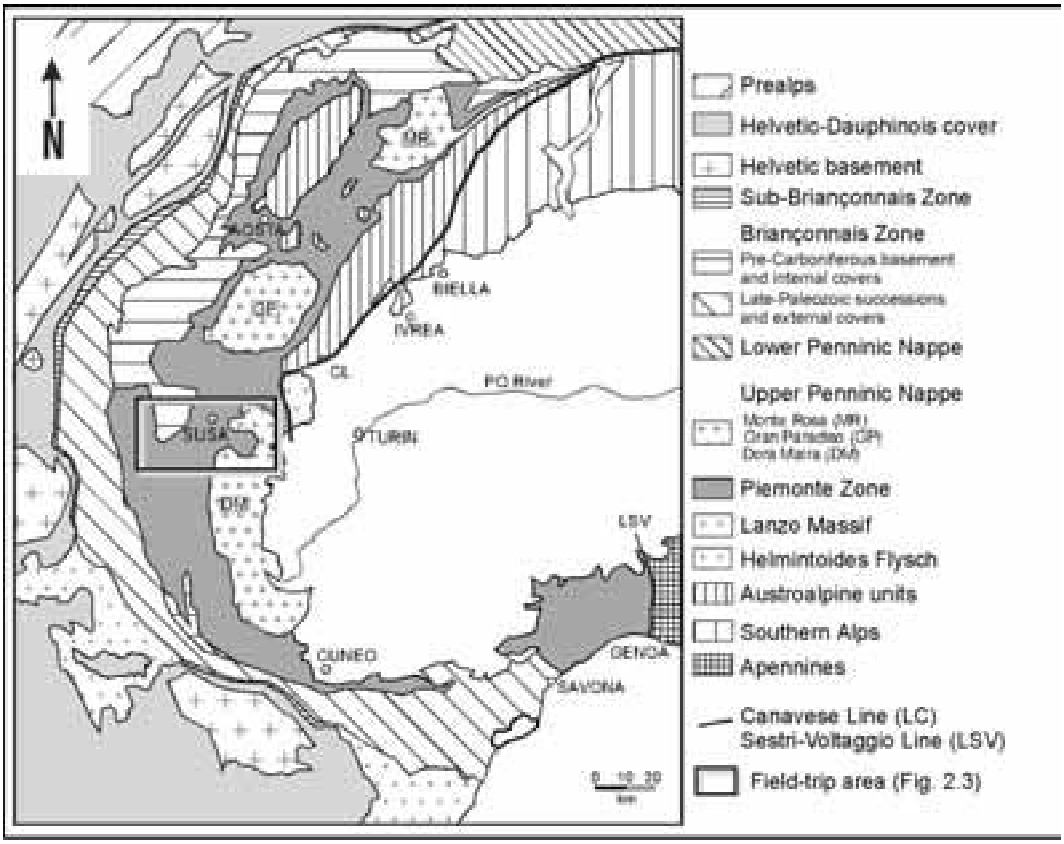

Figure 4 - Sketch-map of the main geo-structural units of the Western Alps (modified from Cadoppi et alii, 2002).

by the Alpine metamorphism.

These domains, showing strong paleogeographic connotation, are separated by main tectonic discontinuities, each being characterized by its own geologic homogenous history, partially independent from the one beside.

The area of interest for the field-trip is at the core of the Penninic domain. It shows both preserved mesozoic oceanic crust units ("Piemonte Zone s.l".), and continental crust units (Dora Maira, Ambin) and related sedimentary covers. Within the sedimentary cover a great importance is related to the widespread calchshistes or "schistes lustres" (Deville et alii, 1992).

Stages of Alpine orogenesis and models for structural interpretation

The hystory of the alpine chain is commonly subdivided into three main stages (Unziker & Martinotti, 1987). The first event, known as Eoalpine, took place between the Cretaceous and the Paleocene. It corresponds with the long pre-collision evolution of the convergent margin, characterized by the formation of a first sheet chain and by HP-LT metamorphism (Pognante, 1984). The further events are notice in literature as Mesoalpine (lower Eocene-Oligocene) and Neoalpine (Miocene-Present).

These latter events represent the true collision phases between the European continent and the Adria microplate. The result of this complex evolution process is a double vergent crust structure (figure 5):
1) a European vergent chain (or "alpine chain s.s") constituted by a sequence of translated tectonic systems, from the Cretaceous, towards the European foreland, and 2) a southern tectonic one, (the "South-Alpine domain"), which since the Neogene assumes a prevailing African vergent direction.

The Illustrative Notes of the Geologic Map of Italy scale 1:50000 (Maps 132-152-153 "Bardonecchia"; Map 154 "Susa") evidence a very important aspect of this interpretation of the Alpine orogenesis: the "axial

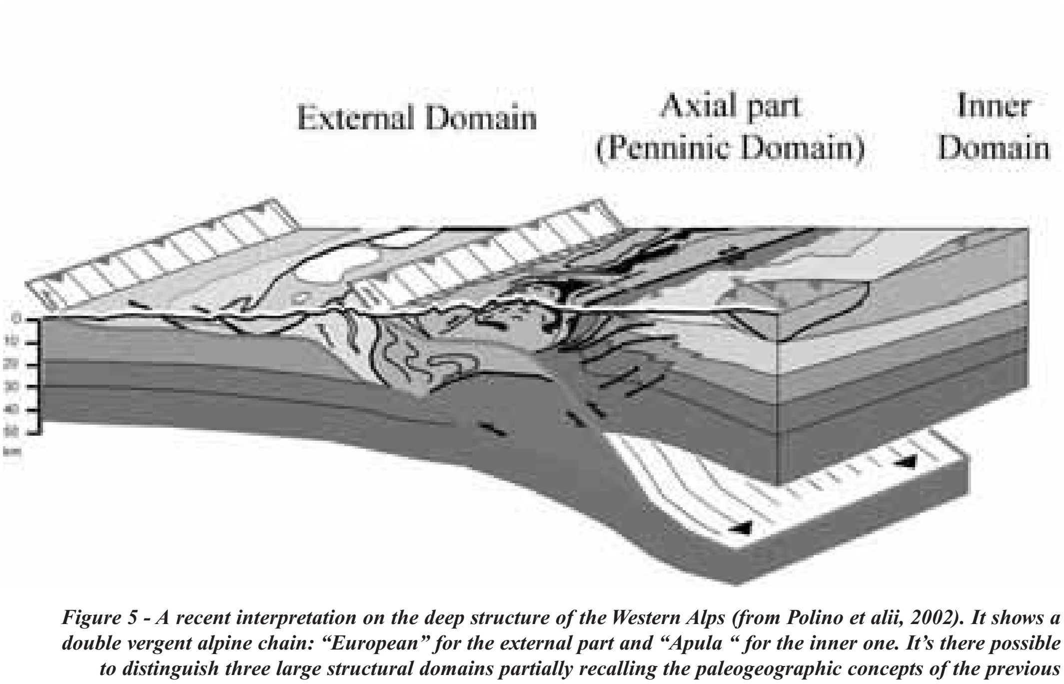

Figure 5 - A recent interpretation on the deep structure of the Western Alps (from Polino et alii, 2002). It shows a double vergent alpine chain: "European" for the external part and "Apula " for the inner one. It's there possible to distinguish three large structural domains partially recalling the paleogeographic concepts of the previous interpretativemodels of the NW-Alps:
- an "inner domain", related to the collision system (upper plate) and corresponding to the South-Alpine domain for the old Authors;
- an "external domain" represented by the foreland, called Helvetic-Dauphinois Domain;
- an "axial part" (the Penninic Domain) delimited by the Insubric line in its inner part and by the Penninic Front to the outside.

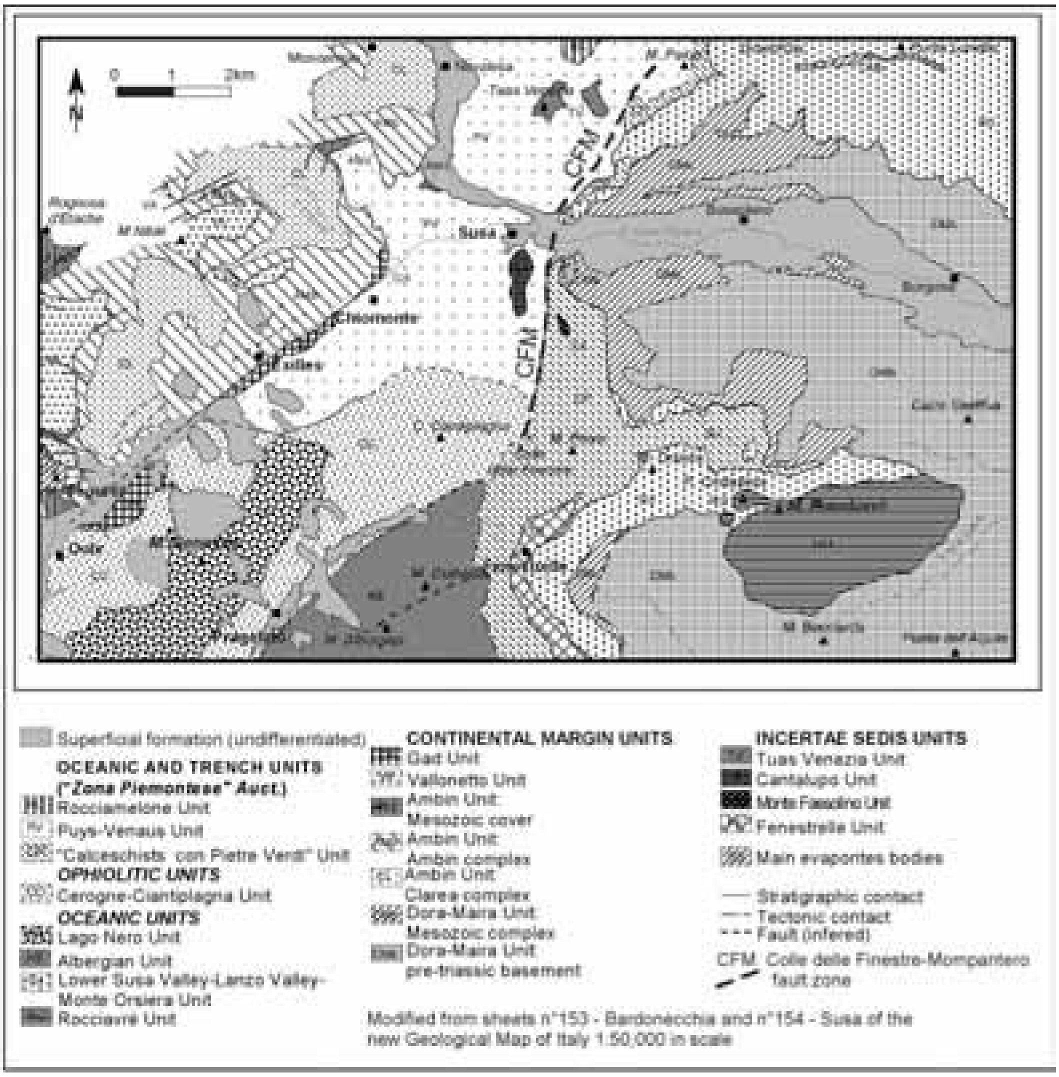

Figure 6 - Sketch-map of the main tectono-structural units of the field-trip area.

part" of the Western alps, constituted by the true collision chain, appears completely detached from the inner and external zones.

This one contains all the units that have suffered metamorphic events associated to subduction and collision. In order to distinguish them it has been introduced concepts as tectonostratigraphic unit ("rock volume delimited by contacts and represented by a stratigraphic succession and/or a metamorphic evolution and/or a structural setting that differs from the adjacent rocks"; Dela Pierre et alii, 1997) and tectonometamorphic unit used by Spalla et alii (1998).

This has been done in order to obtain a geologic maps representation that "offers the reader information on the structural and metamorphic evolution of two different units, even though stratigraphically uniform" (figure 6).

Structural Units of the Susa and Chisone Valleys

Based on these principles, the bedrock units that characterize the study area can be substantially attributed to two different groups:

1. those referring, from a paleogeographic point of view, to the interposed oceanic basin (the Tethis) between the European and Insubric paleocontinents,

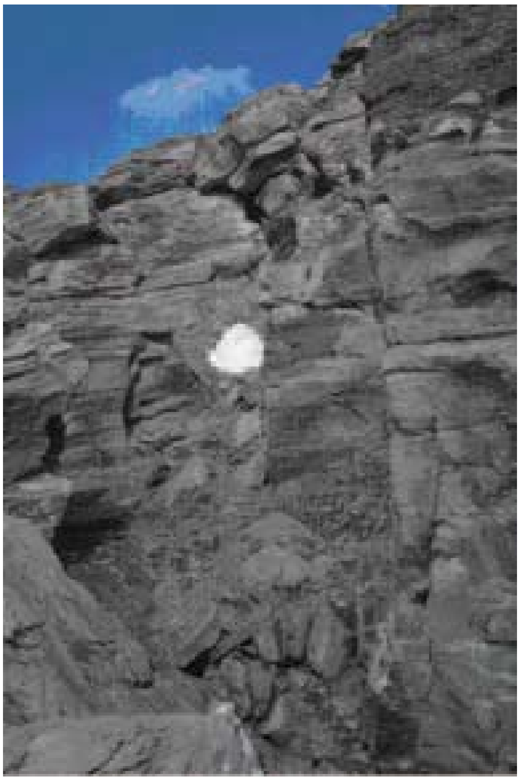

Figure 7 - Fractured calcschists of the Piemonte zone outcropping in a slope affected by a deep-seated gravitational deformation.

Figure 8 - "Eyed gneisses" of the Dora-Maira Unit.

Figure 9 - Pillow lava at the Colletto Verde, Monginevro area.

and its side continental margins;
2. those referred to continental crust and their relative sedimentary covers.
The first group involves:
- the units with sure oceanic origin rocks: crust (gabbros, serpentinites, pillow lavas; Figure 9) or sedimentary cover (former radiolarites) deposited on oceanic crust (Rocciavrè, Lower Susa Valley - Lanzo Valley - Mount Orsiera, Albergian, Lago Nero Units). But also those units that, in presence of ophiolites (Lagabrielle, 1994), are not possible to demonstrate of oceanic origin (Aigle, Vin Vert, Cerogne-Ciantiplagna Units). Unit types are characterized by their degree of metamorphism
- the uncertain geographic position units, possible convergent trench deposits (metamorphic marls and marly limestones derived: calcschists and related rocks; Figure 7) (Puys-Venaus, Calcschists and "Pietre Verdi", Rocciamelone units).

Figure 10 - Mesoscale folds into the white marbles of the Dora-Maira Unit (Rocca Bianca quarry).

The second group comprises:
- the continental margin units with Mesozoic terrigenous sedimentary successions (Trias-Upper Cretaceous) (Dora-Maira, Ambin units with related Mesozoic covers; Figures 8, 10; Gad and Vallonetto units)
- "incertae sedis" units such as Fenestrelle, Tuas Venezia, Cantalupo, Monte Fassolino units, which

represents relics of detached permo-mesozoic covers whose basement is unknown.

Field itinerary

DAY 1

The Chisone Valley

The field-trip starts from the Southern Piemontese Plain near Turin. Here from the Highway A21 the bus takes the Turin bypass. At the exit of Orbassano it follows the Torino-Pinerolo Highway.
In Pinerolo, the city at the mouth of Chisone Valley, the bus run along State Road SS23 towards Sestriere, up to the Village of Fenestrelle, then to the Fenestrelle fortification.

Geomorphological context

Cirio C. G., Giardino M.

In the central sector of the Western Alps ("Alpi Cozie") the Chisone and Germanasca Valleys (Figure 11) are part of the Chisone Basin, a water-drainage system (590 km^2 of total area) developed in between Susa Valley (to the North) and Pellice Valley (to the South).
The main valley of the water-drainage system is the Chisone one: approximately 56 km-long from the southwestern valley head (Appenna Mount, 2981 m a.s.l.) to the mouth in the high Piemontese Plain (Abbadia Alpina, 400 m a.s.l.).
The Chisone Basin is usually subdivided into 3 areas:
• the Upper Chisone Valley, between valley head and Usseaux/Fenestrelle villages;
• the Medium Chisone Valley, between Fenestrelle and T. Germanasca's confluence;
• the Lower Chisone Valley, from that confluence till the valley mouth.

Chisone Valley's width varies between 5 and 10 km and its altitude between 3280 m (Punta Rognosa) and the approximately 400 m at the valley mouth. The Chisone Torrent flows through high Piemontese Plain for about 12 km, before joining T. Pellice SW of Pinerolo.
The two main tributaries of Chisone Stream, both on

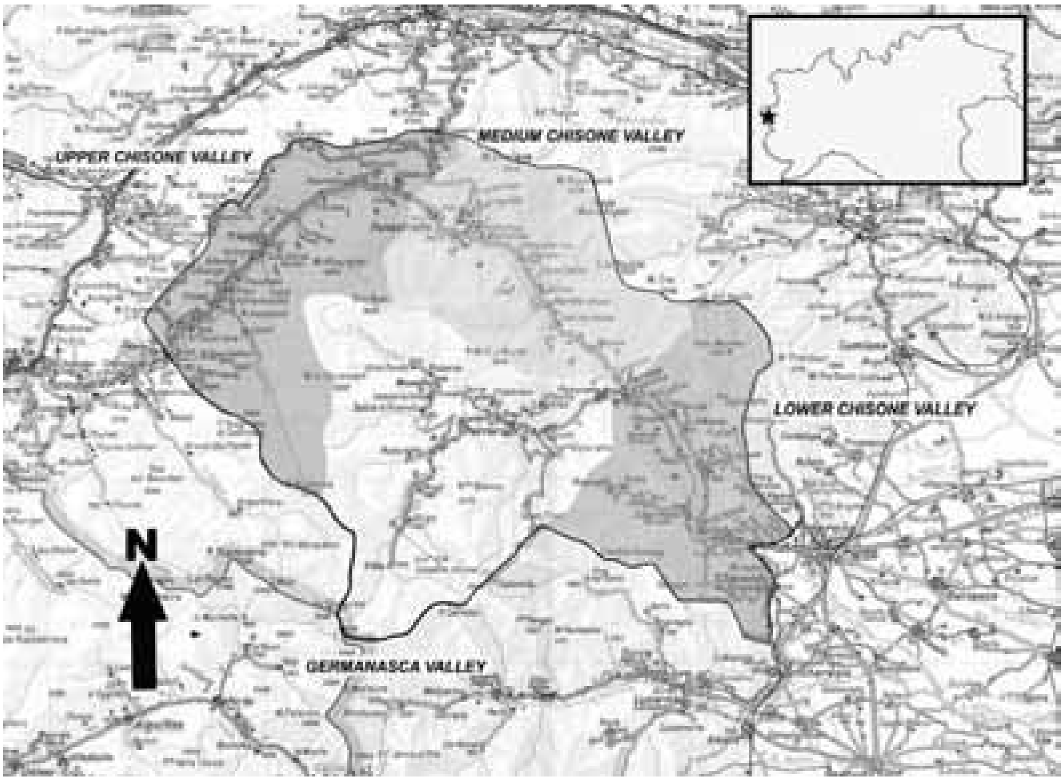

Figure 11 - Road map and main subdivision of Chisone Basin.

its right bank, are the Germanasca and the Risagliardo Streams. The first one descends through Germanasca Valley for more than 25 km and flows into Chisone Stream beside Perosa Argentina town. T. Germanasca's watershed covers a surface of about 170 km^2 and it is separated from Chisone Basin by a ridge culminating in the Massiccio dell'Albergian (3043 m).

The Risagliardo Stream, characterized by a small drainage basin and a length of only 8 km, joins Chisone Stream below Villar Perosa town. Morphologically the Chisone Valley appears to lack a proper valley head, which is located instead in the Sestriere Col's large saddle (2033 m). Three small creeks (Chisonetto, Rio del Riv, Rio Croux), descending from the upper part of the basin, converge 1 km below Sestrieres's saddle to form the main stream. From a geographic point of view, Chisone Stream's source is in the head of the Troncea Valley, the main tributary of the High Chisone Valley.

Chisone Valley lacks of a cirque at the head of the main valley. Tributary valleys, instead, are divided by high ridges (above 3000 m) which conserve, in proximity of valley heads, evident traces of alpine glacial erosion, as large cirques and moraines. These morphologic characteristics are in agreement with the recent thesis of Giraud (1985) and Sereno Regis (1985). In contrast with previous geological literature (Geological map of Italy, sheet 67 "Pinerolo"; Blanchard, 1952; Gabert, 1962), they stated that during LGM no unique valley glacier developed along the entire Chisone Valley. Glacial traces recognized in the valley, in fact, would have been produced by small glaciers, developed in the tributary stream valleys, which probably reached the main valley bottom and joined, but never overtopped main valley's axis.

The lack of a main valley glacier is furthermore confirmed by the presence of a medium-Pleistocene huge alluvial fan, localized beside the town of Perosa Argentina, 15 km upstream the valley mouth (Giraud, 1985; Carraro, 1987). This alluvial fan, formed by Chisone Stream's tributaries on its left bank, originally damned the whole valley's cross section and was downcutted by stream erosion only recently. In the sector of valley localized below Perosa Argentina, lacustrine deposits are outcropping: they belong to inferior plio-pleistocenic epoch and are locally affected by deep deformations.

The U-shaped aspect of Chisone Valley would have not been produced by glacial erosion but it would have been related to the different vulnerability of various structural units to weathering and erosion (Cadoppi et alii, 2002).

Slopes morphology in the sectors of valley below 2000 m is connected to the effects of fluvial processes, weathering and mass movements occurred in post-glacial age.

In some areas, the large and flat valley bottom's areas (Pragelato's plain) were created by Chisone Stream and tributaries' depositional process. Chisone Stream's deposits interdigitate with sediments of tributaries' alluvial fans (Polino et alii, 2002).

The effects of gravity locally obliterate the traces of pleistocenic glacial erosion and more recent fluvial processes. Many traces of large deep reaching gravitational deformation (counterslope scarps, trenches) surveyed in the high valley, along the drainage divide that separates the Chisone Basin from the adjacent Susa Valley (Polino et alii, 2002) and near Fenestrelle town (Cadoppi et alii, 2002).

Large landslide masses have been localized in both valley slopes in the proximity of Soucheres Basses. The NW slope of Albergian Mount is affected by a large slide, that detaches considerable masses of material along subvertical fractures (direction N60) in the bedrock. Frequently shallow landslide (soil slip) affect the topsoil constitued by unconsolidated materials.

A special note need to be added regarding the seismicity, being the Chisone Valley part of the Pinerolese seismic district,which is the major one in NW Italy; it is charachterized by present low to medium energy events with hypocentre depths of 5 to 15 km and maximum magnitude values of 5 to 6 (Capponi et alii, 1980). The historical data (since 1300 a.D.) indicate few events with MCS intensities of about VII-VIII. Data about geometry and kinematics of possible seismogenic structures for the 1980 earthquake (M= 4.8) indicated an extensional tectonics evolution of the Pinerolese district contrasting with compressive tectonic regimes prevailing in the NW-Alps. The isoseismal maps of major earthquakes in the area (1980 and 1808 events suggests the control of seismic wave propagation by ENE-WSW and NNW-SSE structural discontinuities.

The Dora-Maira Unit

Cadoppi P., Giardino M.

From the geological point of view, most of the Day 1 (Chisone Valley) and Day 2 (Germanasca Valley) field itineraries are developed through the the Dora-

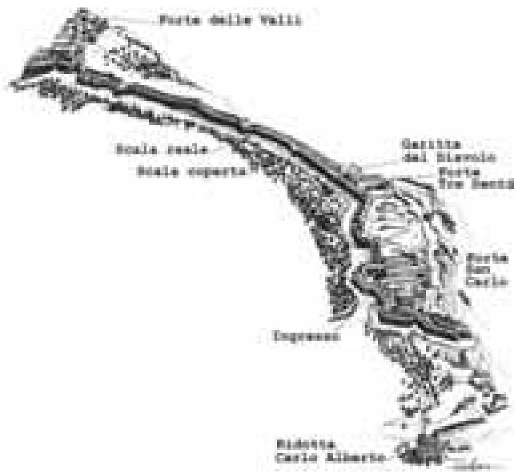

Figure 12 - The complex of Fenestrelle Fortification. From bottom to top of the figure: Carlo Alberto redoubt, main entrance, San Carlo Fort, Tre Denti Fort, Evil sentry-box, covered stairway, royal stairway, Delle Valli Fort. (Progetto San Carlo, 2003)

Maira Unit. Along with the Monte Rosa and Gran Paradiso nappes, the Dora-Maira Unit represents a slice of continental crust belonging to the Upper Penninic Domain (Sandrone et alii, 1993), strongly affetted by the HP-LT alpine metamorphism. The Dora Maira Unit extends between Susa and Maira valleys like an ellipsoid of 25 km width and 70 km length. From a paleogeographic point of view, as well as the other internal massifs (Monte Rosa and Gran Paradiso), it has been interpreted as part of the paleo-European margin (Debelmas and Lemoine, 1970; Dal Piaz et alii, 1972). More recent interpretations (Hunziker & Martinotti 1987; Polino et alii 1990) propose a paleo-African margin position for the Dora-Maira instead.

The Dora-Maira (Figure 13) shows a complex assemblage of crustal slices of paleozoic rocks, sometimes separated by narrow mesozoic thrust sheets. It can be distinguished an upper complex, represented by a precarboniferous polymetamorphic basement and a lower monometamorphic complex composed of (permo-carboniferous) metasediments.

Variscan metaintrusives with an intermediate to granitic composition are widespread in both mono- and polymetamorphic complex (Cadoppi and Tallone, 1992).

Mesozoic metasediment units are also present of prevailing carbonatic nature. Their relationship with the basement has been strongly re-elaborated during the alpine tectono-metamorphic event, for which their stratigraphic nature is not always clear.

The Fenestrelle Fortification

Stop 1.1:

field-trip presentation

The Fenestrelle fortification (Figure 12) is the symbolic monument of the province of Turin. It is nicknamed the Piemonte's "Great Wall of China", due to the 5 km-long fortification wall extending from the left bank of the Chisone to the Catinat plain. 635 metres higher up. The wall contains interminable covered stairway consisting of 4000 steps that stretch along the mountain ridge and touches all the strategic points from the lower citadel to the upper embattlements.

Fortifications begun by the French and extended by the Savoys in 1727. This enormous fortified complex is made up of three forts: San Carlo, Tre Denti and Delle Valli, in addition to the redoubt completed by Carlo Alberto (Progetto San Carlo, 2003).

DAY 2

Germanasca valley

The second day of the field-trip is devoted to the visit of the "open-air monitoring laboratory" of Germanasca valley; from Pracatinat, along the State Road SS23 the bus goes downvalley to Perosa Argentina, where starts the Provincial Road 169 of Germanasca Valley. Stops are along the valley up to Praly's Village (Figure 14). After the visit of the Gemansca Valley the bus returns to the Pracatinat Environmental Center.

The "Open-air monitoring laboratory" of natural instabilities

Lollino G.

Germanasca Valley's basin is characterized by a strong heterogeneity of the gravitational phenomena. Since a few years these phenomena, present at various eleveations, are followed by the Department of Geo-monitoring of CNR-IRPI section of Turin, in collaboration with the environmental territory local offices (Piemonte Region, Province of Turin, Prali Municipality).

The particular geomorphological setting of the area, the presence of wide instability phenomena that involve large portions of the bedrock and the steepness of the slopes represent some of the main causes of this gravitational phenomena concentration. The high social-economic value of the zone and the presence of a remarkable variety of gravitational phenomena within a small area make Germanasca Valley an experimental laboratory basin that CNR-IRPI uses

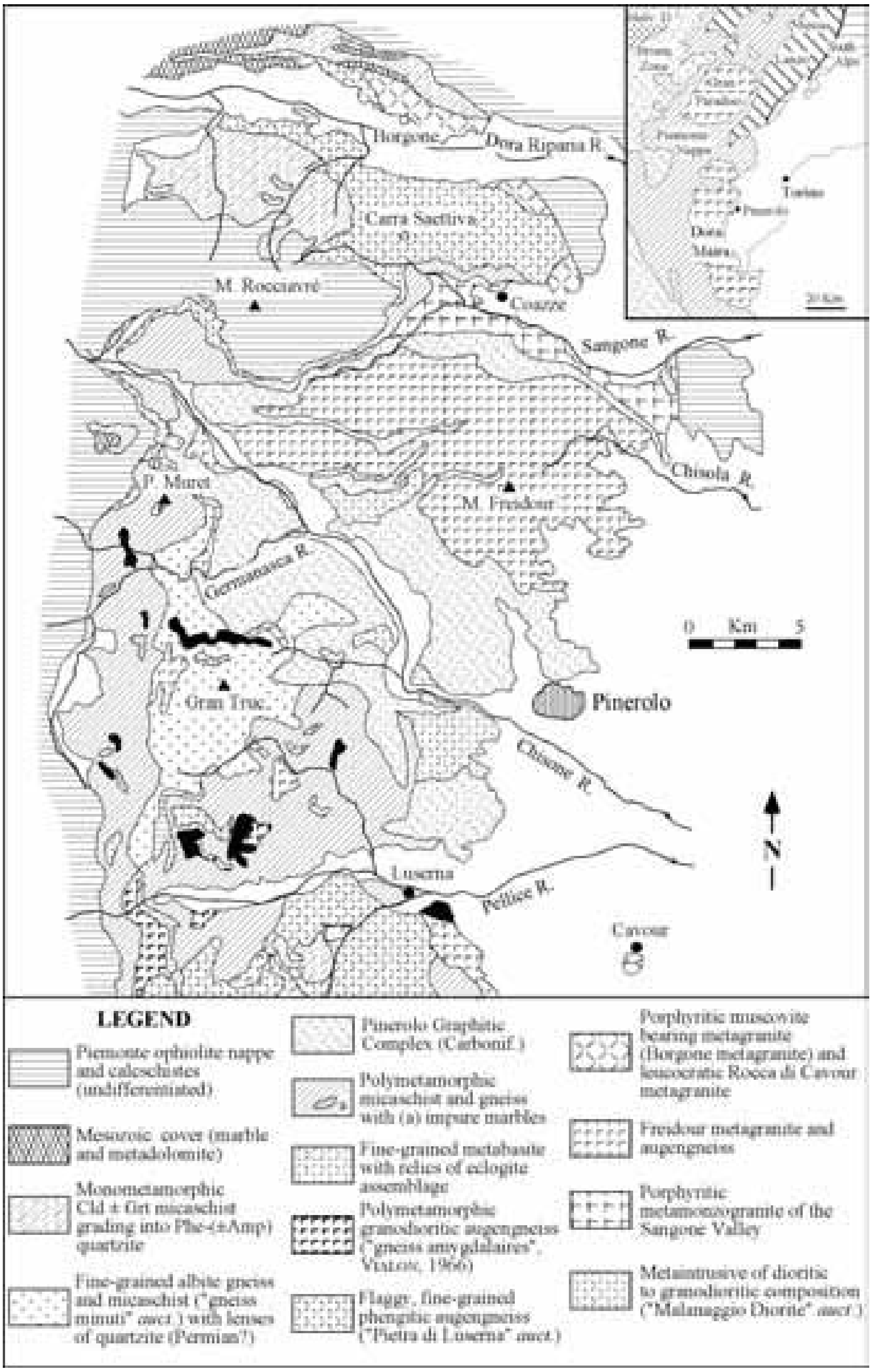

Figure 13 - Geological sketch-map of the Northern part of Dora-Maira Unit.

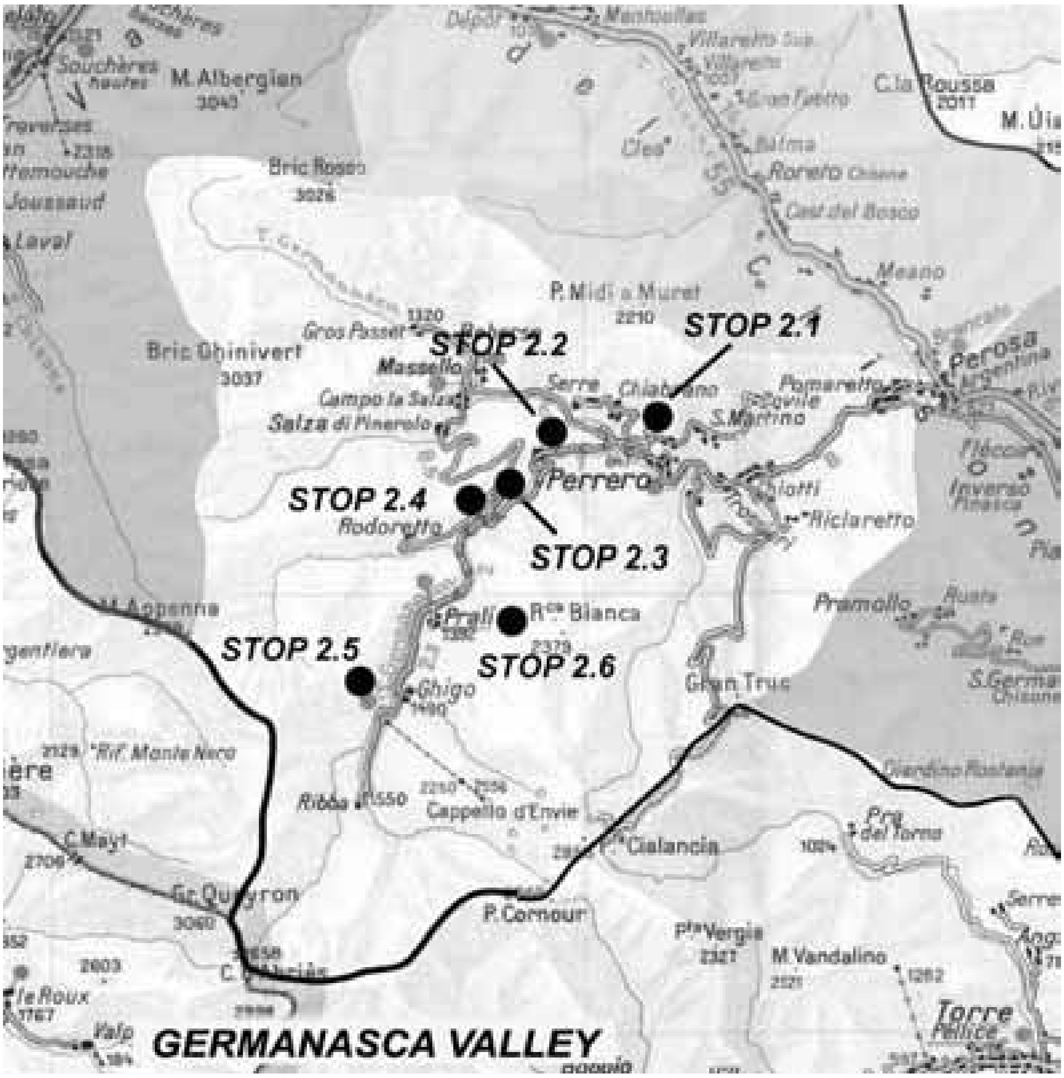

Figure 14 - Road map and main subdivision of Germanasca Basin.

for developing and testing new series of innovative monitoring technologies.
Therefore it has been planned, and already partly realized, a complex monitoring system constituted by integrated net sensors in order to actively control a series of of possible damage to within the infrastructures and the valley activities.
This experimental laboratory has allowed to plan and to test advanced monitoring systems and develop innovative methodologies to control, forecast and prevent the territory from the various instability phenomena.

In particular, the monitored sites and their relative monitoring systems are:

- The A.I.S. application on Perrero landslide - stop 2.1
- Pomeifrè: monitoring rock falls phenomena (microseismic net and total station) - stop 2.2
- The complex Gardiola landslide (integrated system composed by extensometers, total station, video movement recognization) - stop 2.4
- Prali' snow avalanche site (monitoring integrated system with satellite transmission) - stop 2.5

Stop 2.1:
The A.I.S. application on Perrero landslide
Lollino G.

In correspondance to the village of Perrero, on the left side of middle Germanasca valley, it's possible to observe a large-slope instability phenomenon that interests important portions of the bedrock.

Such phenomenon has several zones at different activity degrees, one of the most active is surely the one comprised between the village of Traverse and Perrero.

The phenomenon is long known and followed constantly by the local environmental agencies.

Throughtout the year 2003 a Automatic Inclinometer System (A.I.S. system - property of CNR-IRPI) and a continuous measure piezometer have been added to the monitoring net previously installed by the Piemonte Region.

The A.I.S. (Figure 15), a new equipment for deep geo-technique measurements, patented by CNR-IRPI Section of Turin, continuously inquires the entire length of the tube (measures = 0.5 m) and gives an almost continue deformed inclinometric so it is able to exceed the traditional limits as "fixed inclinometric columns" that only monitor some vertical points, often inadequate, as amount and position. A.I.S. also furnishes more realistic and correlated values to the contemporary pluviometric and piezometric ones. The A.I.S. is planned to work automatically, continuously and by remote control. This allows to obtain precise information on some important parameters useful to characterize the unstable slope movement as main direction and entity of the movement, speed and acceleration. Besides, the possibility to modify in real time the measures frequency, allows to adapt the system to the monitoring phenomenon evolutions.

In some sites the contemporary use of these two equipments, controlled by a remote station, have furnished important indications on the relationships between the gravitational phenomenon reactivations and the piezometric level variations (Lollino G., 1992; Lollino et alii, 2002a; Lolino et alii, 2003)

Figure 15 - Automatic Inclinometer System instrument.

Stop 2.2:
Pomeifrè: monitoring rock falls phenomena
Baldo M., De Renzo G., Sambuelli L.

The study area corresponds to a small portion of the left side of middle Germanasca Valley located approximately 3 Km above Perrero, in proximity of Pomeifrè villages. The area extends from the river bed of T. Germanasca (elevation 980 m a.s.l.) to elevation 1150 m, corresponding to a rock fortification; it includes a 450 m-long segment of the road immediately east of Pomeifrè (Figure 16). The site is characterized by landslide phenomena and it's valuable for the realization of a monitoring plan because:

- during 1996 a hundreds of cubic meters rock block fall interrupted the Provincial Road;
- enormous blocks along the river bed evidence the repeating of landslide phenomena in time;
- the frequent debris cover along the road indicates the presence of diffuse instability events.

A geo-structural study of 1999 evidenced the particular bedrock geometrical setting along the slope and its natural predisposition to landslides.

The bedrock, mostly constituted by gneissic and mica-schists pertaining to the Dora Maira Unit, is characterized by a high fracturation degree that isolates a series of enormous blocks.

The rock block fall phenomena have always represented a problem for monitoring, because they are "accidental" and casual individual events of paroxysmal nature. That's why it was studied an innovative

Figure 16 - Landscape view of the Pomeifrè rock fall area.

way to monitor the zone in order to foresee possible block detachments.

Two monitoring tipologies have been adopted, a punctual and an areal one.

For the punctual type monitoring, it has been used a topographical robot total station, in order to control the potential unstable blocks.

For the areal-type monitoring, because already experienced methodologies were not available, it has been attemped to apply geophysical methodologies.

Total Station

On the opposite valley side to the study area a topographical monitoring system has been installed, composed by a self-assisted total station in an independent and heated protected lodge.

Throughout a modem connected to the analogic conventional telephone line, the data is sent to a remote station at the CNR – IRPI of Turin; the total station is connected to the Workstation and the control software is able to make continuous measurement cycles on the prism placed on the opposite side.

The eventual survey of anomalous situations regarding presetted parameters is pointed out through predefined e-mail, fax and sms messanges.

The particular type of event and the strong limitations in adverse weather conditions of the topographical system, have made indispensable the usage of an areal survey system constituted by a local micro-seismic net (figure 17). Such net has been devoted to individualize and analyze the dynamic signals from the examined area.

A successive monitoring phase foresees the study of the event origin in the particular area.

Stop 2.3:

Historical talc mining activities: the Paola Mine

Barbero T.

A wide sector of the Dora-Maira Massif, from Pellice (Grange Subiaschi) to Sangone Valley (Grange Martinetto and Rolando), through Germanasca (Envie, Sapatlè, Pleinet, Comba la Fracia, Malzas, Fontane, Crosetto, Maniglia) and Chisone Valley (la Roussa), has been the center of talc mines and quarries since XVII century, representing nearly the total national production. In the past centuries the extractive activity of Germanasca Valley was essentially organized in the exploitation of single outcrops, by quarries scattered through all the productive zone but of limited proportions and generally familiar conduction. The unprepared old miners, the often unregular course of the veins and the rather elevated mine location, caused the disarrenging development of the extractive

Figure 17 - Particular of micro-seismic data logger.

activity. It was not until the early twentieth century that a true and productive mine conscience was not taken that also permited the selection, transport and elaboration of the talc.

Along the right slope Germanasca Valley the abandoned mines of Envie, Sapatlè, Pleinet, Comba la Fracia and Malzas are localized, while Fontane is still acti-

ve. Since 1995 near Pomeifré a new gallery has been opened, called " Rodoretto" finalized to exploit the underground of the homonymous Valley (Sandrone et alii, 1987; Genre, 1997).
Around Fontane, the talc embedding rocks are essentially marbles, micaschist, gneisses and rare metabasite, all of them refered to Dora-Maira Unit (Borghi et alii, 1985; Borghi & Sandrone, 1990). Fontane talc deposit, of which Crosetto is the only current active mine, is the most important of Italy and one of the most important in Europe, as production entity and quality of the produced talc (Cian et alii, 1984; Sandrone et alii 1990).

Stop 2.4:
The complex Gardiola landslide
Allasia P., Baldo M., Giordan D., Godone F.

After the intense precipitations and the particular weather conditions between October 13-16, 2000, the river basins of the North-Western Italy have been interested by fluvial floods, torrent floods and landslide phenomena. In particular, along the left slope of Germanasca Valley near Salza di Pinerolo, the meteorological event has caused the activation of an important landslide phenomenon: the Gardiola Landslide (Figure 18) (Lollino G. et alii, 2002b).

From the post-event analysis, there were effective local indications (fissures on the road surface, base erosion on the left bank of the Germanasca torrent, road turn wall bulge, wall protection detachment) that the landslide movement had involved and put to risk the main road. The survey also evidenced the existence of a wide sector involved in the landslide, not only along the mentioned road but also in the western and eastern nearby sides. In particular the north-eastern sector resulted to be a strongly reactivated, high-risk instability phenomenon. The morphology and the dimensions of the unstable area could in fact provoke a collapse and obstruct the bottom-valley. Therefore it was then necessary to quickly start the observations on the phenomenon evolution. In order to control the risk a temporary monitoring net was established, to which later defense works were associated. These were: 1) the Germanasca's torrent bank erosion structures and 2) a by pass tube to avoid temporary bottom-valley obstruction by a possible dangerous natural dam, if the instability phenomenon reactivated itself.

The studied area of Gardiola landslide is constituted by ancient landslide and eluvial-colluvial deposits

Figure. 18 - General view of Gardiola landslide; white circles identifies the target reflectors' position.

Figure 19 - Robotized total station.

covering the bedrock constituted by mica-schists pertaining to the Dora-Maira Unit.
The landslide evidences are distribuited approximately below elevation of 1300 m, where tension cracks and fissures indicates the top of the unstable landslide body, down to Germanasca torrent.
The landslide area, complex type, spreads for a total area of approximately 40,000 mq.
The information drawn by the observation of several editions of the official topographic maps and by aerial photo interpretation has evidenced that the landslide

Figure 20 - Particular of target reflector

reactivation is part of a bigger and older event that interests the entire left side of Germanasca Valley, between the villages of Serrevecchio and Colletto delle Fontane.

In order to monitor the present day landslide a robotized total station (Figure 19, 20) with an automatic coincidence system has been installed on the opposite side, inside a protected lodge.

Such system is subdivided into three levels:
1. topographical measurement station on the opposite side to the one involved in the landslide movement;
2. control and management system of the robot station;
3. remote communication system for the data acquired by the monitoring system.

For safety reasons, the computer has been installed at the Workstation that controls Pomeifrè landslide and it's connected to the total station throughout a radiomodem and directive antenna.
The data transmission to CNR – IRPI remote station occurs throughout a traditional analogic telephone 56K and a telecontrol software.
The system is programmed to automatically execute three hours measurement cycles. These values are memorized and transmitted every day to the Geomonitoring Department of the CNR - IRPI Section of Turin.
In order to continuosly monitor the dangerous situations, also in adverse atmospheric conditions, 3 potenziometric extensometers have been installed. The instrumentation is constituted by 3 electric wire extensometers (E1, E2, E3) and an electric thermometer. Besides, the system is planned to carry out a comparison in real time of the indicated values with presetted limited ones. Exceeding values activate an alert telephone procedure to predefined adressees. Inside the acquisition data unit it's possible to have a GSM transmission module (cellular + modem) while the alimentation module is located outside. It's composed by a photovoltaic panel with current regulator and backup battery (Figure 21, 22).

Stop 2.5:
Prali' snow avalanche site
Giordan D.
In the upper Germanasca Valley, Prali's Municipality, there are a series of avalanche sites that interest the bottom-valley zones occupied by human activities and structures.
In particular, near Orgiere and Malzat, a snow avalanche phenomenon of great dimensions is known that has caused in the past several damages to the infrastructures of the zone (Capello, 1979; Informative Avalanches System Piemonte Region - Province of Turin, 2001). The most important cases of the last 50 years have taken place there in 1969, 1972,

Figure 21 - Data logger of potenziometric extensometers' network.

Figure 22 - Particular of potenziometric extensometer.

1978 in 1986 and 1993; in all these cases serious damages have been registered to civil manufactures. In the past, in order to contrast this serious situation, a series of snow protection nets have been installed to partially safeguard the zone. Currently an ulterior amount of nets have been installed side by side to the previous ones to protect the detachment area. Parallely with the nets an experimental monitoring system has been planned and realized in order to supply valid information on the snow mantle situation in the detachment zone.
The goal for such monitoring network is to supply a series of useful information on the correct management, to the local authorities (Mayor of Prali and local Avalanches Committee), on the avalanches subjected zone.

Phenomenon description

The detachment zone of the Orgiere avalanche covers an area of approximately 1400 m^2, maximum elevation 2500 meters. The difference in level of the snow-avalanche path is approximately 1050 m high.
The detachment area is exposed to the South, in a leeward zone usually characterized by intense aeolian snow accumulates. It's essentially formed by steep slopes, sometimes strongly tilted (medium slope 45°) with rock outcrops emerging especially SW. The area is a pasture land.
The sliding zone is constituted by a very narrow channel, with a series of cliffs, ending at the bottom-valley as a mixed alluvial fan (Figure 23). The detached snowy body from the higher portions of the slope (maily deep avalanches) acquires an acceleration and a partial transformation from a sheet avalanche to cubic type avalanche, increasing its destructive power. In the past, the avalanches force has often threatened part of Orgiere and Malzat, also destroying a series of garages and a gas station.

Monitoring method

This monitoring system forsees the survey of a series of snow-meteorological parameters in the detachment area (Figure 24): height of the snowy mantle, temperature, intensity and direction of the wind, parameters usually analyzed by the data processing centers of the territory.
However, the one of mount Selletta also monitors other parameters as the sliding entity of the snowy mantle (already installed and working) and the workload entity of the snow protection nets with a series of load cells installed in one of the elements (still not active).
The monitoring network is not only based on these measures but it also takes advantage of other data from the other traditional processing centres. These data are taken every day and weekly data, as dictated by AINEVA (Snow and Avalanches Inter-region Association), that allow better understanding of the inner snowy mantle transformations.
These data are collected at the municipality offices and from here transmitted to the CNR-IRPI at Turin. For the data transmission it has been decided to use an innovative system throughout a bidirectional satellite parabolic antenna, so that the Prali Municipality could be autonomous in case of natural disasters.

Stop 2.6. and 2.7:

Viewpoints on Upper Germanasca Valley: glacial history and slope dynamics

Barbero T., Giardino M.

The last stops of the field-trip along the upper part of the Germanasca Valley are mainly devoted to a geomorphological overview on the high elevation alpine environment; this will be useful to understand the typology of landforms, geomorphic processes and controlling factors, in order to get a better definition

Figure 23 - Landscape view of Prali's snow avalache site

hanging valley sills, such as that of Vallone della Longia, 500 m above talweg of Germanasca Valley, left side. Glacial deposits are preserved along the valley bottoms and sides: At "Bout du Col" they cover the flat internal side of an asymmetric ridge. The original toponym of this place ("Bô du Col") means "Wood of the Hill" and should be referred to the ancient larch wood that used to be here before the starting of railway construction in the Savoy Kingdom, 19th century (Grill, 1924).

of natural hazards in the area and to develop adequate monitoring and mitigation measures.

For an easier description of the topics regarding following Stops, the upper Germanasca valley can be subdivided into 3 sectors, corresponding to different segments of the hydrographic network: 1) the upper course of Germanasca torrent, 2) the Vallone delle Miniere, 3) the segment below their confluence, down to Prali Village.

Upper course

The upper course of the Germanasca Torrent, from the head to the Vallone delle Miniere confluence at the Giordan village, shows typical glacial landforms, either erosional or depositional.

Along the bottom of the valley head, morainic ridges dammed the valley: later the Lago Verde ("Green Lake") formed, together with other minor glacial lakes now silted up and changed into peat-bogs. Cross-sections through the valley sides show several steps and counterslopes: they correspond to the remnants of glacial landforms (terraces and elongated depressions) parallel to the valley length. A good example is that of "Selletta" (up to Pommieri village) whose toponym means "small saddle". Other remnants of glacial erosion along the valley sides are the

Vallone delle Miniere

In the Vallone delle Miniere area, glacial deposits cover the left tributary valley of the Colle Rousset and the lower part of the Vallone delle Miniere down to Lausarot village. Their geomorphic expression range from morainic ridges to a widespread cover of subangular-subrounded boulders (erratics). The right tributary "Vallone dei Tredici Laghi" ("Valley of Thirteen Lakes") is a hanging valley where the prevailing erosional processes of glacial origin formed roches moutonnes and overdeepened hollows, later filled by meteoric and running waters.

A widespread cover of coarse debris and fine colluvial deposits characterizes the foot of major rocky slopes and scarps at higher elevation than 1900 m. Here debris cone and debris sheets are fed by gravity-induced phenomena linked to physical weathering (mainly frost action) on highly fractured rock masses (Franceschetti & Merlo, 1972). Debris accumulations are often reworked by the action of snow and ice (nival and cryogenic processes). The resulting landforms are avalanche cones, protalus ramparts, and ice-cemented rock glaciers (Haeberli, 1990; Tricart, 1992).

Along the slopes at lower elevations, the highest mean temperature, the tree cover and the prevailing rain versus snow precipitations make easier chemical weathering: the results are fine eluvial-colluvial depo-

Figure 24 - Automatic snow- meteorological station.

sits prevailing over debris-covered areas.
Alluvial coarse deposits are along the Germanasca torrent at the valley bottom and at the mouth of the tributaries. A large post-glacial landslide detached from Giulian Mount and dammed the Vallone delle Miniere Torrent close to Punta Cianagli slope: it originated a small swamp.
Similar phenomena are visible in other sector of the Upper Germanasca valley such as the Vallone di Envie Southeast of Prali.

Below the confluence

The Upper Germanasca Valley below the confluence of the Vallone delle Miniere has a wider, flatter valley bottom. Glacial deposits are predominantly well distributed along the left slope (Pomieri, Cugno) while the right slope is characterized by large relict landslides ("paleolandslides" sensu Carraro et alii, 1979). The single area of these relict landslide accumulations varies between 0,1 to 2,8 km^2: They are mainly distributed between 1350 and 2300 m a.s.l., and only some of them (Sapatlè, Bosco Nero, Miande Rabbiere, Indiritti) still show the original geomorphic expressions ("landslide cones"). Other relict landslides are deeply remodeled by rill/gully erosion and torrents activities. Even present-day landslides contribute to rework the early post-glacial environment: The Maiera e Praiet landslides have been recenty reactivated involving single small parts of the large old landslides.

Extractive activity in Upper Val Germanasca

The white marble ("marmi bianche e bardigli") quarries of Val Germanasca, at least active since late sixteenth century, were exploited with great discontinuity during the past centuries.
Localized in impervious places sometimes reaching 2000 m a.s.l., lots of these quarries were impracticable in the winter and sometimes even throughout the year, as the one of Rocca Bianca. This last one, located at quota 2128 m, in correspondence to the head of the Vallone Faetto, has been exploited since 1584, as the sign testifies on the workers shelter rests (Berti, 1996). The exploitation has continued until the beginning of the eighteenth century. Currently, in this location, the only quarry still active remains Maiera, quota 1930 m, on the right slope of Val Germanasca di Prali.

The "Vallone delle Miniere" is named after the presence of copper-pyirites deposits, iron and cop-

Figure 25 - The main scarp of the Rocca Bianca quarry, where white marble of the Dora Maira sedimentary cover were exploited since late sixteen century

per mineral, extracted until the XIX century. Such deposits are localized along the left slope below Colletto di Viafiorcia and are associated to quartzites, metagabbros and serpentinites (Novarese, 1895; Grill 1925). On the left slope of Val Germanasca di Prali, between the towns of Ghigo and Villa, it's possible to find bigger and economically less important rests of exploitations of the same mineral, near the Poset or Pouset, also described by Grill (1926).

DAY 3

From the Chisone to the Susa Valley

The Day 3 of the field-trip starts at the Pra Catinat Environmental Centre. It follows Chisone Valley upside from Fenestrelle to Sestriere (Stop 3.1) along the State Road SS23. Then the bus takes the State Road SS24 up to the Village of Cesana Torinese (Stop 3.2).

After the lunch in Cesana Torinese, the field-trip continues downvalley to the Sauze d'Oulx "paleolandslide" (Stop 3.3), then to Serre La Voute Gorge, eastern end of the Oulx-Salbertrand Plain for the overview on Cassas Landslide (Stop 3.4).

Then it continues downvalley to the Exilles Fortification for an overview on Clot Brun large-slope instability (Stop 3.5).

Afterwards along the Road SS24 the Susa city will be reached. Here it will takes the Highway A32 to the town of Turin.

Stop 3.1:

Sestriere: 2006 Winter Olympics site at the Chisone "valley head"

Giardino M., Audisio C.

Morphologically, the Chisone Valley appears to lack a proper valley head, which is now located in the Sestriere Col's large saddle (2033 m). This seems to be related to the glacial history of the Susa-Chisone watershed in this area: as shown in paragraph 3.1.1, during LGM no unique valley glacier developed along the entire Chisone Valley, the tributary glaciers being responsible of main glacial erosion and deposition in the valley.

Three small creeks (Chisonetto, Rio del Riv, Rio Croux), descending from the upper part of the basin, converge 1 km below Sestrieres's saddle to form the main stream. From a geographic point of view, Chisone Stream's source is in the head of the Troncea Valley, the main tributary of the High Chisone Valley.

The large saddle at the Chisone head hosts the well-famous Sestriere ski resort.

After crossing southwestward the Sestriere saddle, the field trip continues down to the Ripa valley, upper part of the southern branch of the Susa Valley.

Geomorphological context and recent geological evolution of the Susa Valley

Susa Valley (Dora Riparia river basin) is located immediately West of Turin and constitutes an articulated and complex water-drainage valley system (Figure 26). Along the main arquate valley oriented approximately E-W, three secondary branches join: 1) the Dora di Bardonecchia fed in its first part by Valle Stretta and Valle di Rochemolles, 2) the Dora di Cesana, with two right tributaries: Valle Thuràs and Valle Ripa, and 3) Cenischia valley.

Based on the planimetric articulation and above all on the geomorfologic evolution, Susa Valley can be subdivided into three segments:

- a higher part, formed by the highest zones from the actual alpine watershed to the Oulx-Salbertrand Plain (1.000 m a.s.l.);
- a middle part, between Oulx-Salbertrand Plain, below the confluence of the two Dora's tributaries, and Susa town (500 m); at the Dora Riparia and Torrente Cenischia confluence;
- a lower part, from the Cenischia confluence to the valley mouth on the piemontese plain, where it's possibile to find the morainic hills of the Rivoli-Avigliana's amphitheater.

The river basin is developed from Mount Pierre Menue (3.505 m) to the high Po plain mouth 300 m. The higher tops, where the articulated watersheds ridges separate it from the contiguous river basins, often surpass 3.000 m of elevation, the greater one is represented by Rocciamelone with its 3538 m. The only actual existing glacier in the Italian side is the "Ghiacciaio dell'Agnello" in the Ambin Massif, currently in fast retreatment.

The long-term geomorphological evolution knowledges indicate the Valle di Susa basin as a wide zone, at the head, that originally belonged to the western side of the alpine chain and now makes part of the eastern side after the continuous systematic migration of the main watershed from the inside towards outside (Staub, 1934). Such process would have happened, according to Staub, essentially during the Miocene. In the lower Pliocene, analogous to the other main western alpine valleys the lower part of the valley was

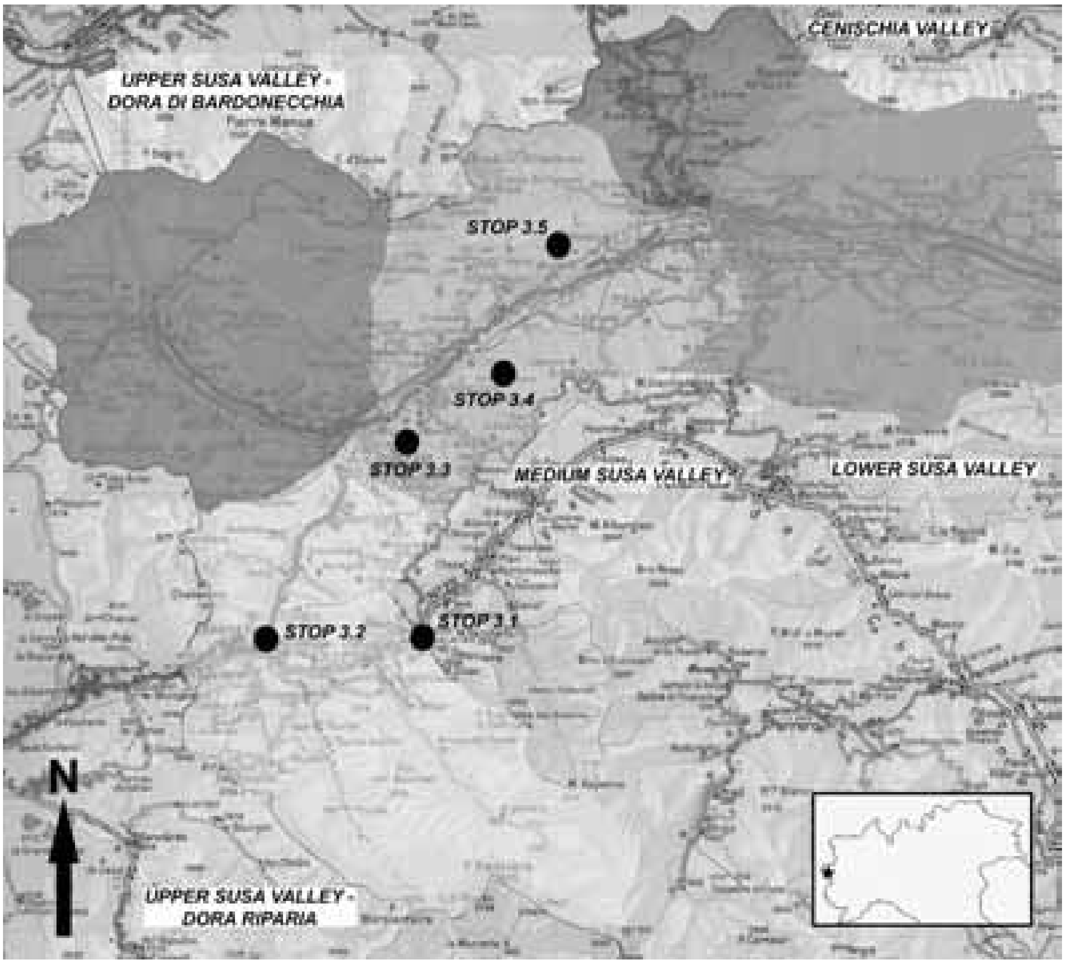

Figure 26 - Field-trip road map and main subdivision of Susa Valley.

still invaded by the sea. The retreatment of this last one has been followed, in the medium Pliocene and the lower Pleistocene, by the deposition of a swamp-coastal-fluvial succession (“villafranchian” facies).

The Quaternary glaciers have begun their existence and evolution from the Alpine relief and from the accumulation surface of the “villafranchian” succession: their progressive erosional deepening has brought to the re-excavation of the valley parallely to the previous one. The glaciers traces are very recognizable in the single erosional landforms and in the well preserved deposits, on both sides of the valley. Recent studies on the superficial formations realized for the CARG project (new Geologic Maps of Italy scale 1:50.000, “Bardonecchia” and “Susa sheets (Figure 27) applied Allostratigraphy (NACSN, 1983) to the analyzed area (Baggio et alii 1997; Giardino & Fioraso, 1998). These studies have shown that, at least in the last two phases, Susa Valley glacier feeding happened throughout two main basins (Cenischia and Dora Riparia) with very different geological history and characteristics. Such studies have interpretated the glacier traces in the Susa Valley pertaining to at least two different phases:

1) the first phase, attributed to the Penultimate Glacier Maximum Advance (the middle Pleistocene one). It comprises the rare forms and the badly preserved deposits from the “ Bennale Allogroup” (Cenischia River basin) and “Clot Sesian Allogroup” (Dora Riparia river basin).

2) The second phase, corresponds to the last gla-

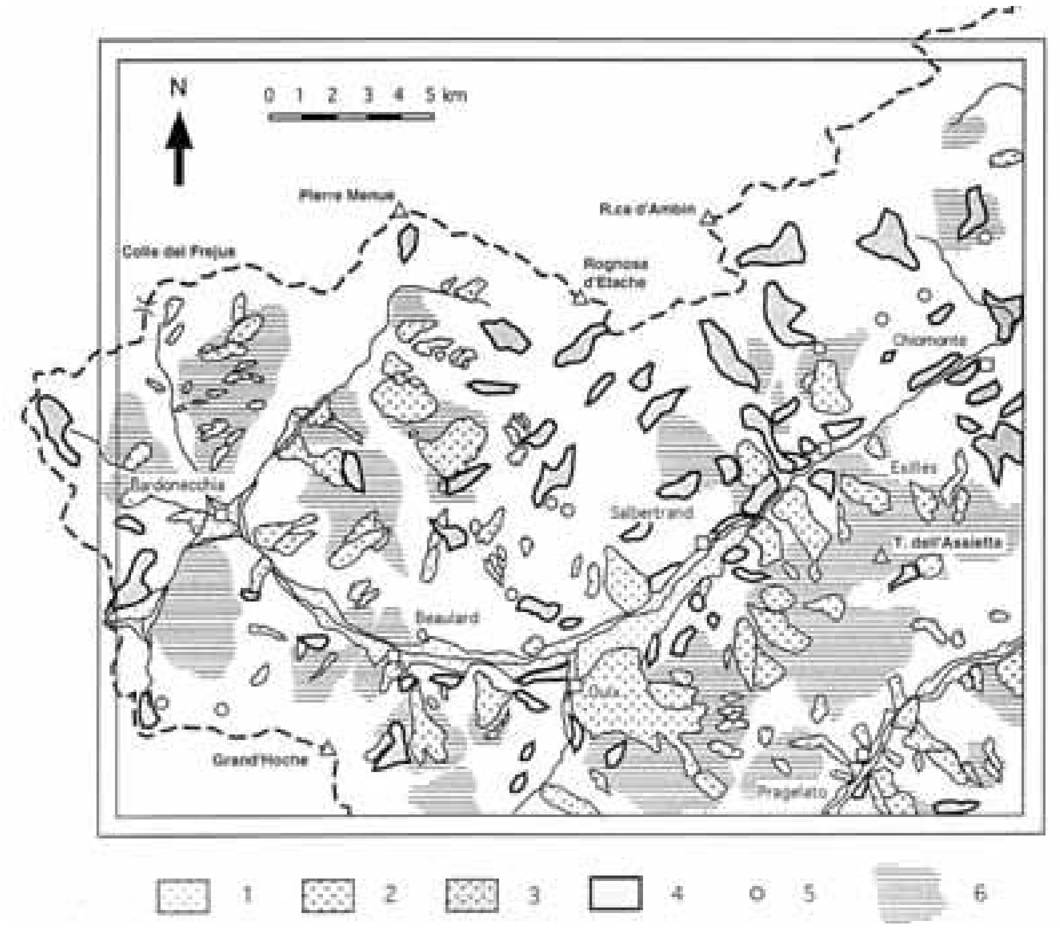

Figure 27 - Quaternary deposits and large-slope instabilities distribution in the area of the "Bardonecchia" sheet of the Geological map of Italy 1:50,000 in scale.
1) lacustrine and alluvial deposits; 2, 3) landslide deposits; 4) glacial and fluvioglacial deposits 5) well cemented etherogeneous deposits; 6) deep-seated gravitational deformations. (from Giardino & Fioraso, 1998).

cial maximum (LGM) and to its retreat cataglacial episodes. This one comprises a variety of landforms and better preserved deposits as the "Allogruppo of the Moncenisio" (Cenischia River basin) and the "Allogruppo of Salbertrand" (Dora Riparia Basin). During the field trip it will be possibile to observe some important element of the stratigrafic succession corresponding to the second glacial phase.

The post-glacial evolution of the Susa Valley is strongly characterized by various gravity instability processes. The excursion will show some large landslides and deep-seated gravitational deformations of Upper ande Medium Susa valley (related to the surface releasing tensional processes because of deglaciation processes and controled by the structural settings of the relief) as well as very common different type of landslide phenomena (mainly rock fall and slides).

Within the modeling surface for the higher altimetric zones we can't forget the cryogenic and nival phenomena, still active today in absence of large glacial masses. In the lower elevation zones and in the valley bottoms the erosional and depositional processes of fluvial and torrent environments assume preponderant importance, largely conserving landforms and correlated deposits. It has to be remembered that Susa Valley is one of the most affected Western Alps zone by the alluvial event of October 2000.
During the field trip it will be possible to notice nu-

merous traces, mainly relative to debris-flow events along the Dora Riparia tributaries.

Deep-seated gravitational deformations in the Upper and Middle parts of Susa Valley

Giardino M.

The Upper and Middle parts of Valley di Susa is characterized, apart from an elevated number of landslide accumulations, some of them multi-km in size, by the imposing presence of deep-seated gravitational deformations ("DSGD") of the slopes. These corrispond with great mass movements in which the deformational mechanisms don't require continuous surfaces or shear zones for the rock masses translations (Sorriso-Valvo, 1995).

An eventual continuous sliding surface is also not needed to reach the slope's surface; deep deformations and displacement amounts are smaller compared to the size of the phenomenon area, that is comparable to the whole mountain slope.

The importance of these slow and progressive deformational phenomena within the mountains morfogenesis has been more times emphasized by numerous Authors (Zischinsky, 1966, 1969; Radbruch-hall et alii, 1978; Savage & Swolfs, 1986; Varnes et alii, 1989). In the western alpine arc this has been confirmed by regional (Mortara & Sorzana, 1987; Forlati et alii, 1995) and local studies (Puma et alii, 1989; Forlati et alii, 1991; Giardino & Polino, 1997).

The DSGDs involves almost 20% of the total area of Upper and Middle Susa valley.

A characterization of these phenomena has been based on a local systematic study of a series of geomorphological-structural elements (Fioraso, 1994). Visual examples of the following features are presented in paragraph 3.3.7:

- " sliding steps": slope breakups, generally with clear cuts, correspondent to steep rock scarps. The relative movement of the two blocks is mostly vertical, on the same sliding plane. The step is defined "masked" in the case in which the rock surface is extensively covered by detritic-colluvium products:

" trenches": m- to dam-wide, often debris-filled, they represent the superficial morphologic expression of deep fractures opened for tens or hundred of meters (Figure 28);

Figure 28 - top ridge trench in the Clot Brun large slope instability

- " gravity closed depressions": (Figure 29) sub-circle or sub-elliptic holes, with m- to dam-long maximum axis and depth no more than tens of meters. They are localized in weak and loose bedrocks and generally represent the trenches evolution;
- "superficial gravity detachment traces": lengthened depressions, with decametric-hectometric longitudinal size and metric-decametric trasversal one, determined by the gravity sheare discontinuity intersection with the topographical surface. These morphologic element characterize the upper slopes, where deep seated gravitational deformations take place, and the lateral margins of the same deformations.

All these phenomena are distributed throughout the entire Susa Valley: however, the poor geomechanical properties of the metasedimentary units ("calcschists") of the Piemonte Zone, determine a high concentration of deep-seated gravitational deformations along the Susa-Chisone watershed, where the calcschists largely occour. The local development of these gravitational phenomena is also conditioned

Figure 29 - Closed depression in the Clot Brun large slope instability.

by the presence of a regional extensional fracture systems ("Susa-Chisone Shear Zone, Giardino 1 Polino 1997) that control their evolution and kynematic characteristics.

The peculiarity of the Susa-Chisone DSGDs, beyond their dimensions, corresponds with the particularly easy-to-identify rock mass deformation processes. In fact, the surface expression of the phenomena has allowed to identify slope portions characterized by styles and types of deformation somewhat different. Along the watersheds the deformation is expressed by a series of doubled crest due to trenches and close depressions; in the higher zones cross-displacements vary from tens to a hundred of meters and features have kilometric longitudinal development. These superficial elements represent the overtopping sliding surfaces where slope deformation takes place along the pre-existing discontinuity systems oriented N60E.

Such manifestations can be indicated as "lateral spread of ridges" with "brittle" rock mass behavior. Examples can be easily observed at Casses Blanches (Serre la Voute large-slope instability, left side of middle Susa Valley di Susa) and along the M. Clopaca-Cima del Vallone- Quattro Denti ridge (Clot Brun large-slope instability.

In the lower zones, on the slopes the DSGD phenomena are expressed as large-scale inflations and undulations, locally underlined by close depressions (es. Serre la Voute, Val Fredda, Sauze d' Oulx sectors). Along Susa Valley, in rare cases it's possibile to observe the presence of continuous surfaces or shear zones along the slope. Such phenomena, as the "sackung" (controlled by "ductile-type" deformations), represent a different deformation of behaviour induced by the deep seated gravitational movements. The large displacements observable along the ridges are in fact connected to the movements in the lower parts of the slope, where rock deformation often doesn't take place along a preferential deformational surfaces, but through differential movements involving the entire displaced rock mass.

Figure 30 - Elongated depression in the Clot Brun large slope instability.

Stop 3.2:

Contributes of geological knowledge to environmental awareness: the "Geosites Project" and the "Cesana educational site"

Giardino M., Pellegrino P.

This stop deals with the research activities devoted to "areas or territories where it's possible to define a geological and geomorfological interest for natural patrimony conservation" ("geosites"; Wimbledon et al. 1995). The geosite's researches in the Western Alps started up from CNR-IRPI's and University of Turin's projects in collaboration with and supported by local and territorial Institutions (Cesana Torinese Municipality, Turin Province, Piemonte Region) in the context of programs aimed to promote sustainable tourism in the alpine area (European Union Interreg III: "The mountains born of the sea. Sustainable tourism, geology and environment between Dora and Durance Rivers"; Turin Province's: Geosites Project "Landscape 2006").

These collaborations were born at a peculiar time in the history of this land, that of the groundworks for 2006 Winter Olympics, to be held in Turin. The Olympic Games event, seen by many environmentalists as a calamity for the mountains, due to the adjustment/building works of sporting and touristic structures, is thought by others to be also a chance to highlight and to exploit the natural resources of this Western Alps area, and to realize a complete plan for environmental protection against natural instabilities. The challenge was taken up, and Research Institutions are working along with the Public Administrations to analyze the most interesting geosites in-depth, in order to spread the knowledge and to activate consistent paths of sustainable touristic fruition.

The peculiar characteristics of the Upper Susa Valley (large variety of rock units from different paleoenvironmental, structural and metamorphic contexts; present-day highly dynamic geomorphological environments and anthropical territories) made also possible to develop geological/educational products available to the public and to managing institutions, looking for a positive repercussions in terms of spreading of environmental awareness and natural hazard preparedness (Figure 31).

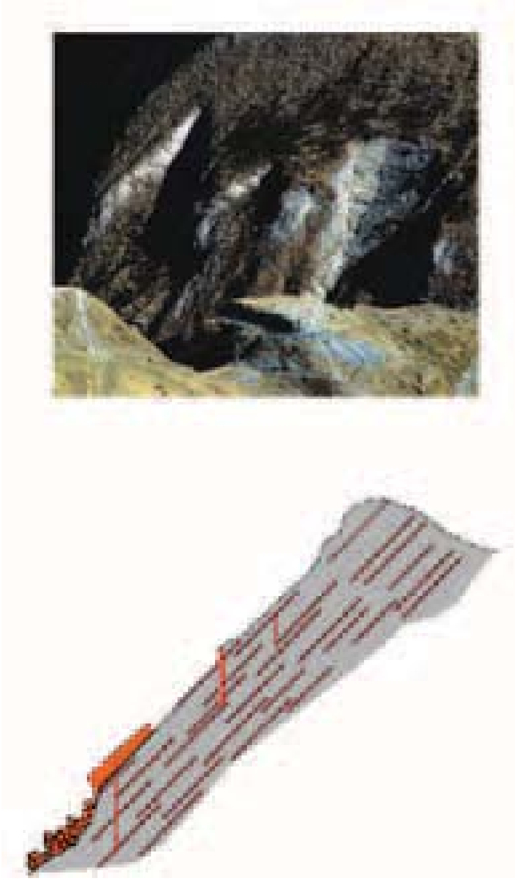

Figure 31 - Images from the "Progetto Geositi": The Colle delle Finestre Landslide (Artwork by Baggio, 2001). The Project is promoted and sponsored by the Turin Province (Servizio Difesa del Suolo) with the scientific coordination of University of Turin (Dipartimento di Scienze della Terra) and CNR-IRPI (Istituto per la Protezione Idrogeologica), section of Turin.

Geosites in the landscape of the Turin Province

A first result was obtained: the popular booklet on the first series of geosites examined (Aigotti et alii, 1999) turned out to be ex aequo winner of the FIST-GEOSITI prize 2001 at the national competition announced by the Italian Federation for Earth Sciences. Now the efforts are focused on the research of new sites (Giardino et alii, 2002) and the realization of an experimental thematic cartography on geology and tourism in the Sangone Valley (Giordan et alii, 2004), that might make it easier for excursionists to "read" the landforms of the mountain and understand both its current and recent evolution and dynamics and the litho-structural conditioning coming from its ancient or recent geological history.

The "Garden of the Rocks" rediscovers Geology

"When was the Earth formed?". "How many different rocks in the mountain! What are their names?. "Is it real that some rocks now founded in the mountains were once hundreds of meters under the sea?". "Why do mountains change so quickly under the effect of the atmospheric agents?".

These are some of the lots of questions that can be asked by tourist observing with a little bit of curiosity the Alps. The answers are contained inside the rocks that form the Alpine landscapes and the mountain environments. However in order to find them you need to know how an "expert eye" looks.

The Cesana's "Garden of the Rocks" is an occasion for everybody, for better understanding, or for discovering for the first time, some of the principal geological aspects that have determined life on Earth as we know it today. After that, one can also focus himself on the history of the Alps, the tectonic and metamorphic phenomena as well as the morphogenesis.

Following the various proposed itineraries the visitors can learn and touch with hand some of the geological and geomorphological aspects of the alpine territory. The approach to the proposed paths is fun and didactic. The topics are exposed in a clear and simple way, on billboards, activity areas and environmental reconstructions. This way people can read, observe and interact with the billboards as well as with the permanent scenographies equiped in the Garden (an ancient prehistoric beach, a small scale reconstruction of the Westerna Alps, free climbing areas, baby "geological" playground, Earth and Man historic evolution, the usage of earth materials in the mountain).

The Cesana's "Garden of the Rocks" is realized to educate with a geological game: looking for alpine landforms and geological structures; understanding the natural processes and evolutionary stages of the mountain environment.

Rediscovering the world around us is the first step for safeguarding the geological heritage.

Stop 3.3:

Potentialities of high-resolution optical images for recognition and monitoring of large landslides: The Sauze d'Oulx "paleolandslide"

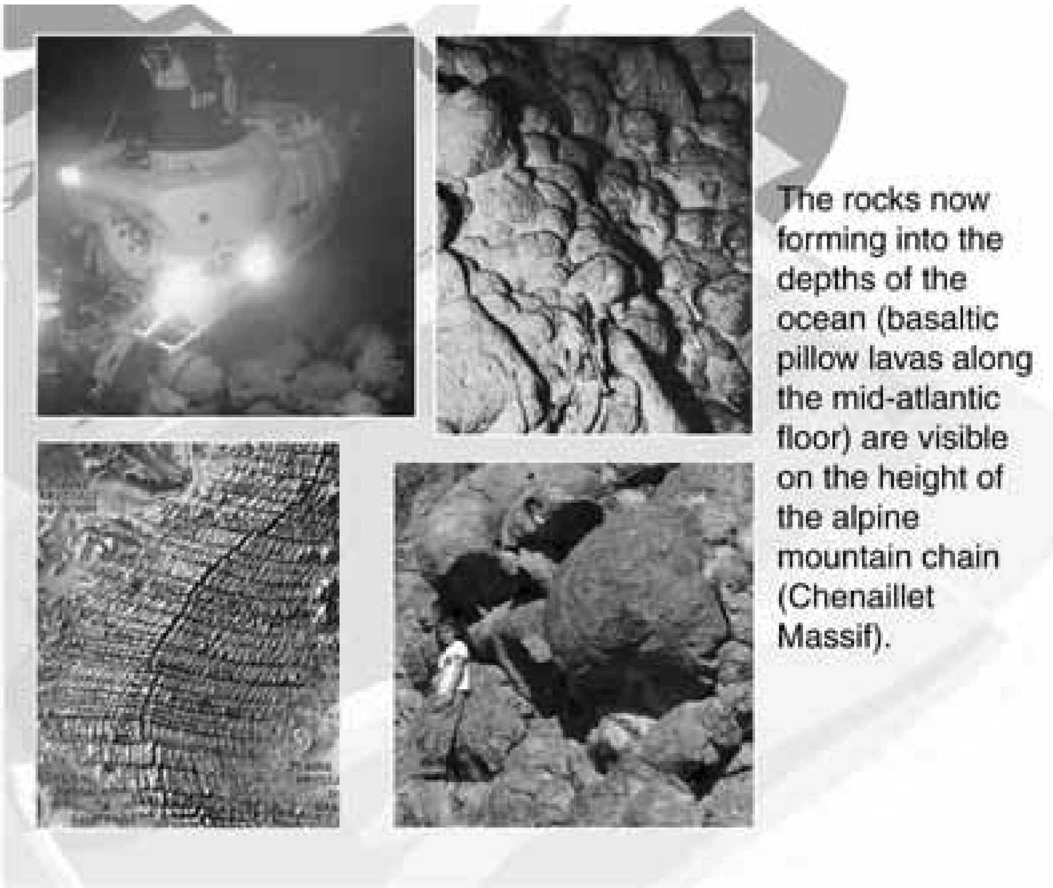

Figure 32 - Images from the "Garden of the Rocks": discovering the origin pillow lavas (Artwork by Pellegrino P., 2003).
The "Garden of the Rocks"of Cesana Torinese is part of the European Union Interreg III Project: "The mountains born of the sea. Sustainable tourism, geology and environment between Dora and Durance Rivers". A Meridiani production, with the scientific contribution of University of Turin (Dipartimento di Scienze della Terra).

Perotti L., Giardino M., Borgogno Mondino E.

After the Cesana stop, the field trip continues down valley along the right slope of Susa Valley between Oulx and Sauze of Oulx. This area is currently intensively studied for infrastructure construction and environmental protection in sight of the 2006 Winter Olympic Games in Turin.

In the old geological literature (Capello, 1942; Sacco, 1943) this area was indicated as a great alluvial fan composed by "reworked" glacial deposits; just recently it has been recognized as one of the Susa Valley zones of intense deep-seated gravitational movements and large landslides (Mortara & Sorzana, 1987; Puma et alii, 1989); These instability phenomena activated after the last glaciation and the consequent tensions release produced by the retreat of the Susa Valley's glacial mass ("paleolandslide", Carraro et alii, 1979), and seems to be also related to neotectonic activity.

In order to test new techniques for the detection of large-slope instabilies and the recognition of present-day superficial deformational rate, a "Verification Methodology" for the potentialities of the PLEIADES/Cosmo-SkyMed (PCS) simulated optical images has been developed and applied to the Sauze d'Oulx area.

The evaluation procedure has been studied and developed according to the following phases. A first phase with ortho-projection of images based on non- parametric models (RFM; Rational Function Model, Tao C. and Hu Y., 2001) in order to appraise the cartographic scale of applicability. A second phase of radiometric calibration in order to bring the radiometry of the simulated images in the correct spectral intervals defined by the Cosmo/SkyMed images. A last phase of technique analysis for specific geometric restitution and classification for the landslide phenomena (Boccardo at alii, 2003).

Geometric approach: orientation tests for simulated stereoscopic couples

Until today the geologic analyses was mainly submitted to the photogrametric methodologies that allow a stereoscopic vision of the territory, or to the low resolution satellite images for structural type studies at small scale in which the 3D is negligible. The new high resolution sensors allow the acquisition of stereoscopic couples of images for the 3D analysis of the territory. The PCS platform will also provide panchromatic stereoscopic couples that could be used for large scale morphological analysis and environmental monitoring. The orientation of the satellite images couples is currently under examination based on the take geometry.

While waiting for the orientation of simulated PCS stereoscopic pairs images it's possible to proceed with some tests on digitized and resampled aerial photograms with PCS anticipated resolution. The attention is focused on the available information and not on the orientation problem.

Figure 33 - Original frame of 1964 with the "Paleolandslide".

Geometric approach: Differential multitemporal Altimetry

The primary interest is the understanding of the derivable altimetric data as a real value added to the landslide problem. In such sense there's an active geomatic approach based on the multitemporal DEM (Digital Elevation Model) differential analysis.

Area Test

The whole middle and upper parts of Susa Valley are interested by deep-seated gravitational deformations. The Chisone-Susa divide is one of the most studied area for lateral spreading, double crests and top-valley phenomena. Apparently the Sauze of Oulx area doesn't have present-day superficial deformation of particular importance or dangerousness for buildings. Nervertheless it could be interesting to monitor the slow but constant movements in time, due to compressive and stretching forces that have interested the deposits of the ancient phenomenon, the "paleo-landslide".

Figure 34 - Original frame of 1964 with the "Paleolandslide".

In this case the analyses will be focused on the main driving cause, that is, on the large DGSD that characterizes the morphology of the area.

Methodology

The approach is based on digital photogrammetric restitution techniques but in the future it will be possible to begin with the satellite images. Such techniques, throughout the stereoscopic couples of images, allow to reconstruct a 3D model of the object and to perform geometric measurements on it. In this case, the object corresponds with the DGSD zone. Two series of frames have been used: 1) a first stereoscopic pairs of the area, from 1964, frame scale 1: 30.000 and resampled upward until the PCS panchromatic anticipated resolution (Figure 33); 2) a second serie of frames (scale 1: 13.000) acquired in 2000, also resampled to 0.70 m (Figure 34). The photogrammetric restitution operations, digitally elaborated on the simulated PCS stereopairs, allowed the production of the digital elevation models (DEM) of 1964 and 2000 for the study zone.

The two DEMS, corresponding to a 40-years time interval, have been compared. To perform this operation the maximum accuracy has been insured in the orientation of the frames in order to limit the propagation of errors in the differential calculations of the so produced DEM.

Results

The two DEMS have been compared elaborating a matricial subtraction (later - first) through a special procedure autonomously developed in IDL language (Interactive Data Language). Positive values indicate probable uplifts, negative values possible sinkings (Figure 35).

Even though the simulated images resolution has been fixed at 0.70 m it's important to keep in mind the imposed limits of the original data scale.

In order to underline just the meaningful vertical movements (those that correspond within the esteemed tolerance) a precautionary threshold has been applied equal to +/- 4m from bibliography (Kraus, 1994). The obtained results are to be considered qualitative. This way considering the limits of the data, the esteemed movement entity is not susceptible of quantitative technical reliability. With all of this, based on punctual verifications, it's possible to verify that these results can be elaborated throughout a qualitative point of view. In the future this procedure could be applied for active slope monitoring foreseeing automated data collection procedures from PCS stereopairs.

These results have been confirmed by the realization of measures on the same study area, elaborated with land and satellite interferometric techniques. They have underlined a vertical evolution comparable to the results of this particular study. In the future it will be possible to apply this methodology directly using stereoscopic couples of satellite images leaving aside the limits currently found by the photogrametric procedure. It will also be possible to realize multitemporal monitoring based on satellite acquisitions that guarantees a high precision and a notable realization speed.

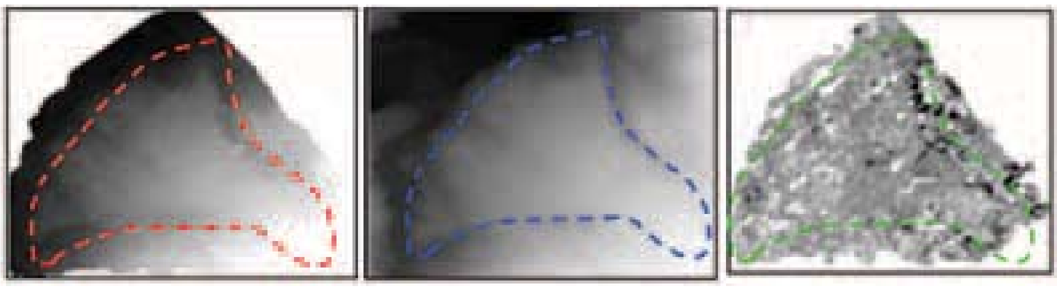

Figure 35 - The operational results of the numerical matricial substraction (DEM); 1964 view (left), 2000 view (center), comparison of the two DEMs (right).

Stop 3.4:
Usage of MIVIS data for the Cassas Landslide study

Perotti L., Giardino M., Alpe F.

MIVIS hyper-spectral sensor

LARA-CNR (Aerial Laboratory for Environmental Researches) has elaborated the MIVIS Airborse system (Multi-spectral Infrared Visible Imaging Spectrometer). This sensor allow the acquisition of 102 spectral bands from the visible to the thermal infrared. In these past years, the geological field has developed numerous advantageous applications with this remarkable spectral resolution (Boccardo et alii, 2003). In particular it's possible to underline, after an accurate digital data preparation, that this data is extremely useful for landslide phenomena analysis. The tests have been elaborated on a MIVIS image taken with a cross-sectional flight on middle Susa Valley includiung the Cassas's landslide.

Pre-processing Data

When dealing with territorial applications it's always important to correctly approach the scale mapping problem. This means that ground object positioning must be coherent for all the used data (often coming from different sources and reference map systems). Such problem can be easily solved with geocoded data such as ancillary and cartographic ones. Not so easy is to face the problem of MIVIS data geocoding maintaining the ground position accurate within an acceptable tolerance range (depending on the nominal scale of the base map it will be adopted). Therefore MIVIS image geocoding is a delicate step to go through; further complexities come from the whisk-broom MIVIS sensor model which introduces many deformations to take care of. Scene geometry has to be corrected. Usual methodology based on simple polynomial approach cannot model such geometry especially in a mountain region as the study area. Ortho-projection has to be done to make MIVIS data suitable for subsequent data integrations (Figure 38).

Cassas's Landslide

The area of the Cassas's landslide (historical event 1957 a.D.) is located on the right slope of the valley above the Serre la Voute Gorge (Figure 36), originated by the occurrence of the Testa del Mottas landslide (historical event 1728 a.D.) and the Serre la Voute deep-seated gravitational deformation (historical events 1957, 1728 a.D.). These instability phenomena dammed the valley bottom originating lacustrine deposits (prehistorical datations on buried subfossil woods: 8380 ± 95 BP; 9525 ± 85 BP). The Cassas landslide develops from a secondary watershed ridge, highest point approximately 1900 m, to the valley bottom, approximately elevation 1000 m.; it is oriented NE-SW. Total area of the landslide is approximately 500.000 square meters.

Images Analysis

The visualization in real colors of the Cassas's landslide evidences the orientation and development of its shear planes inside the landslide and its aerial limits. The distinction between the wooded area and the detritic area appears very simple (Figure 37).

One of the most used syntheses is the False Colors one. In this case it has been obtained associating band 18 to the Red, 10 to the Green and 3 to the Blue (Figure 41). In this image it's possible to appreciate the red and blue tonalities, generally the first refers to forests and prairie zones. On the other hand the blue represents the naked ground where the debris covered areas (Cassas's landslide deposits and Dora Riparia's sediments) and the rock emerging portions are founded (along the watershed). In particular it's possible to notice that with false colors the landslide area is very easy to indentify with respect to forests and prairies.

The possibility to compose images with numerous portions of the electromagnetic spectrum allows a very accurate preliminary analysis of the landslide

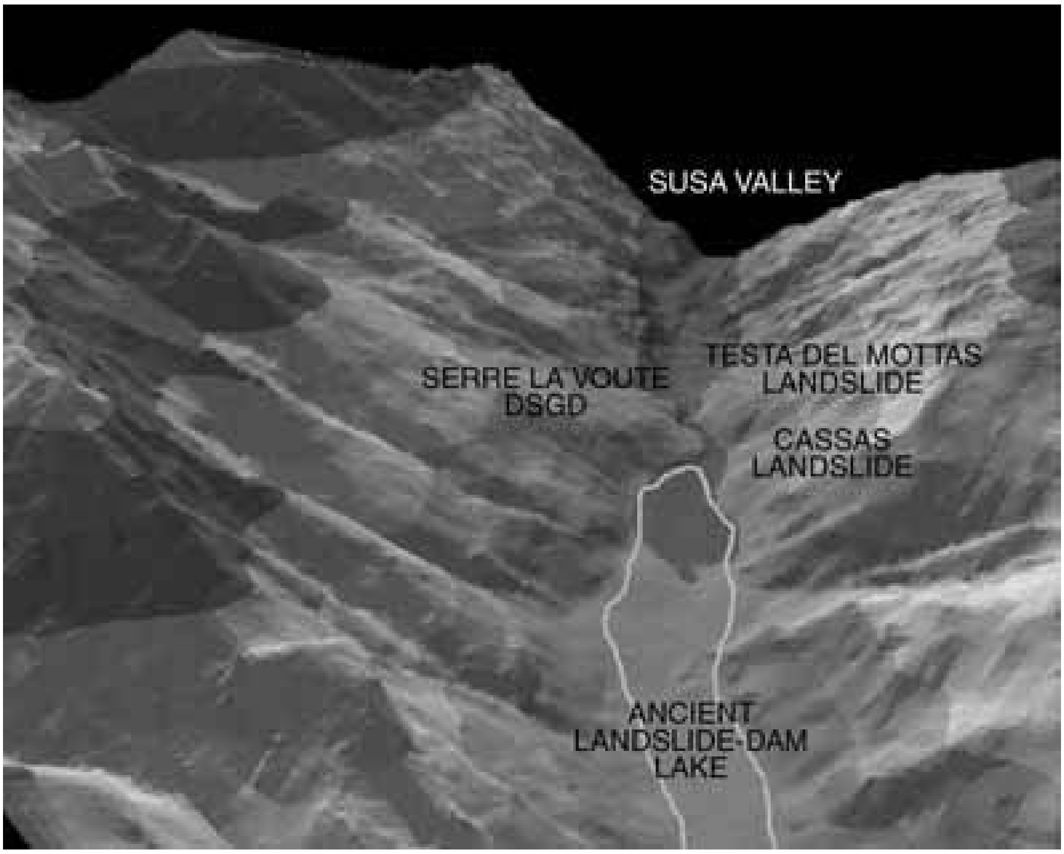

Figure 36 - DEM of the Serre la Voute Gorge.

phenomena, as well as the possibility to directly place the geomorphologic features on the reference cartography (ortoprojected images).
MIVIS Images are a good starting point for landslide phenomena analysis. From a radiometric point of view it's interesting to compose additive synthesis within medium and near infrared regions in order to analyze the covers and other geomorphological features. It's also very important for elaborating measures and tracing the features directly on the ortho-rectified image.

Stop 3.5:

Field activities and G.I.S. techniques applied to the Clot Brun large-slope instability

Giardino M., Ambrogio S., Fontan D.

As well in the upper part, downvalley with respect to the Serre la Voute gorge, several large landslides affect both slopes of Middle Susa Valley: recently they have been individualized and mapped at a regional scale in the "Bardonecchia" sheet of the new geological map of Italy (Polino et alii, 2003).
More detailed characterization and interpretation of single instability phenomena at a local scale is possible through analysis and syntesis of a complete serie of field data, integrated with remote sensing and photo-interpretation data. As an examples of a working procedure, the G.I.S. project for the Clot Brun large-slope instability phenomenon will be presented in the Stop 3.4; here, geomorphic, geo-structural and surface deformational elements have been individualized and kinematically interpreted.
The multidisciplinar study of the Clot Brun large-slope instability has been financed by the Italian National Research Institute on Mountain Enviroment (INMR) with other projects finalized to forecast and prevent the hydrogeologic hazard in mountain regions.

Local geological context

From the geological point of view, the Clot Brun Large Slope Instability cover an area of the internal side of the Western alpine structure where lithotypes of the

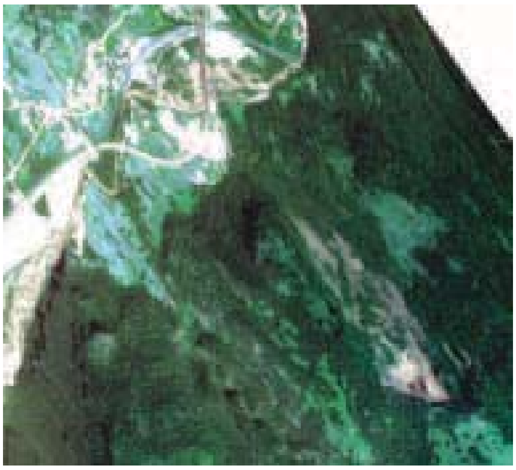

Figure 37 - Cassas Landslide: raw MIVIS image.

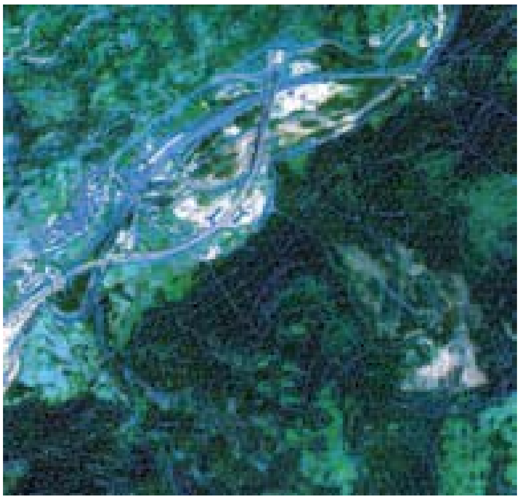

Figure 38 - Cassas Landslide: orthocorrected image with reference cartography, scale 1:10.000.

crystalline basement of the Ambin Massif outcrop, together with a metamorphic cover aged perm-mesozoic. In the Eastern sector of the studied area calcschists belonging to the Piemonte Zone crop out.
The basement unit is known in literature as the Tectonostratigraphic Unit of Ambin (or Ambin Massif). During the Alpine orogenesis it underwent a tectonic and metamorphic evolution. After a subduction event during Cretaceous, (blue schists metamorphism), an Eocenic phase of continental subduction took place (green schists metamorphism). The polymetamorphic basement can be divided in two complexes: the Clarea and the Ambin Complexes. The rocks forming them are pre-alpine volcanics and sedimentary sequences involved both in the Alpine and Hercynican orogenesis.
The Clarea Sequence is the geometrically lower portions of the Ambin massif; it is made of fine-grained micaschists, with intercalations of metabasites, mainly amphibolites and prasinites.
The Ambin micaschists (strong foliated) show alternated clorite-rich and quartz-rich layers and locally they grade to carbonate schists or to conglomeratic-arenaceous micaschists with quartz or white quartzite mm-cm clasts. Metric-decametric lenses of amphibolic metabasites and prasinites are locally associated to the micaschists. The Ambin Sequence is also formed by fine-grained gneisses.
The Mesozoic cover of the Ambin Massif (Permian-Eotrias to Giurassic) during the Alpine orogenesis and the overthrust of the Calcschists nappe detached from the basement in correspondence of a carbonate - evaporite level (carbonatic breccias and “carnioles” auct.). This level allows to recognise an autochthonous cover (not detached and in lower position) and a para-autochthonous one (detached and in upper position). In the studied area the Mesozoic cover, from bottom upwards, is represented by dolomite marbles, calcite marbles and calcschists. In the area of Cima Quattro Denti - Cima del Vallone the marbles are associated to small gypsum lenses. The carbonatic breccias and carnioles are formed by a yellow vesicular calcite matrix, with sharp angled clasts from other lithotypes of the Mesozoic sequence. The clasts can have a weak

Figure 39 (left) - General overview of the Clot Brun large-slope instability: DSGD (red) and landslide (yellow).

Figure 40 - Cassas Landslide:True color MIVIS image.

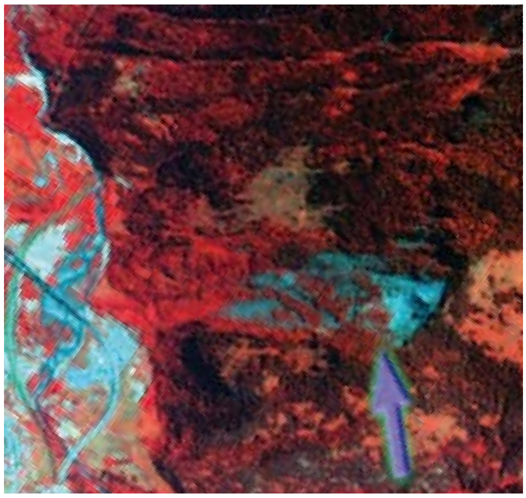

Figure 41 - Cassas Landslide: false color MIVIS image

orientation which seems to indicate cataclastic flow structures.
The Piemonte Zone crops out at the eastern side of the examined area, in correspondence with the confluence between Clarea and Dora Valleys. The main lithotype is represented by grey calcschists, yellow-brown to brown on the weathered surfaces.

Geostructural setting

Two main fault systems have been recognized in the surroundings of Clot Brun area: average directions are NE-SW and ESE-WNW; a joint system with average direction N150°E is associated to them.
Both main fault systems show a high discontinuity degree and are characterised by en-echelon geometries, strongly conditioned by the regional schistosity attitude.
The ESE-WNW system is mainly characterised by single faults with fracture zones of metric-decametric thickness, whereas the NE-SW system is both characterised by single faults and complex fault zones of hm-thickness.

Quaternary Geology and Geomorphology

The glacial deposits of the area are formed by massive and slightly cohesive diamictons (etherometric and etherogeneous sub-rounded pebbles and blocks in gravelly silty matrix). These deposits are distributed in correspondence with flat sectors of the Clot Brun slope. Four "strips" of glacial modelling have been roughly distinguished in the slope by correlation of different allostratigraphic units of glacial deposits, which correspond to four glacial stages of the main Susa Valley glacier.
The upper strip (about 1400-1300 m) is the one which corresponds to Grange Catoube, Rutte and Amburnet glacial terraces (Frénèe Alloformation); the second strip (about 1200-1000 m) is formed by the S. Colombano, Grange Armeita and S. Antonio terraces (Fenils Alloformation). The third strip of modelling (about 1000-850 m) is the one on which the villages of Morliere, Ruinas and Campriond lay (Deveys Alloformation). The lower strip is represented by the saddle isolating the Exilles Fort promontory from the left slope of the valley (Deveys Alloformation).

The glacial modelling acted mainly along zones of intensely fractured rocks, longitudinal compared to the Susa Valley, which have formed aligned rochees moutonnees, scours and stretching NE-SW directions.
Most slope deposits of the upper Clot Brun area are constituted by etherometric rock fragments in a gravel-sand non-consolidated matrix; they form relatively thick accumulations maily related to rock fall phenomena.
In the central and lower parts of the slope, debris-colluvial cover is made of few metres-thick, generally altered deposits, formed by gravel with sharp angled clasts, sand and silt. This cover, partially derived from the local bedrock alteration and from colluvial processes of the weathered products, and partially from gravitational processes, is sometimes involved in small superficial landslides caused by saturation and fluidification processes during very heavy rains ("soil slips").

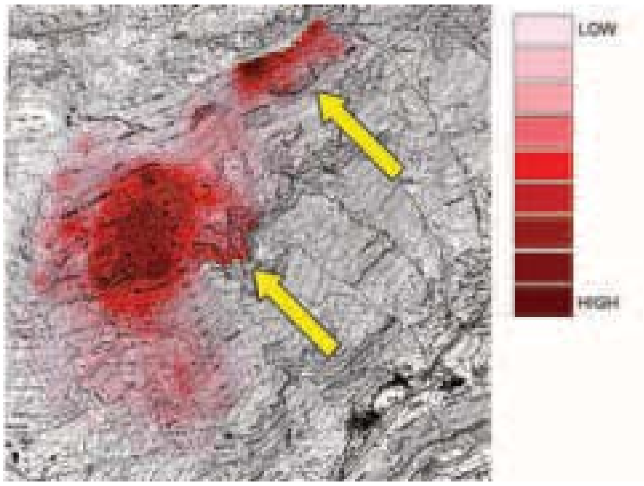

Figure 42 - Hazard map of the Clot Brun area

The alluvial deposits are mainly formed by round pebbles and blocks in gravel-sand matrix (Dora Riparia, Galambra and Clarea torrents). Minor tributaries show torrential and debris flow deposits of prevailing subangular shaped blocks and pebbles in a subordinate sand to slit matrix.

The Clot Brun large slope instability

The Clot Brun Large Slope Instability (18 Km^2) comprehends a sector caracterized by evidences of Deep-Seated Gravitational Deformations of the slopes and several landslides accumulations. The major landslide covers about 2.8 Km^2 and is defined by many morpho-structural elements.

The upper part of the large slope instability is formed by at least two sub-parallel scars, quite well defined; the western part of the upper one (2400 m) is formed by a fault surface inclined by 50-60° towards S and SE, settled in carbonate lithotypes and characterised by strips of breccias with sharp angled etherometric clasts cemented by a carbonate matrix, probably due to dissolution and re-precipitation of carbonate by seepage water. The apparent displacement is about 25 m.

Between elevations 2150 m and 1850 m, the slope is mainly formed by shifted and loosen rock masses alternated to sectors characterised by debris cover. This part of the landslide is also characterised by scarps and trenches, by recent cuts of the turf and by small rock falls, in particular along the left flank of the large slope instability. As well, in correspondence with the edges of the area involved in the gravitational phenomenon, there are N-S and NNW-SSE stretched depression with longitudinal position compared to the deformed area. These depressions represent zones of differential strike-slip displacement; their directions correspond, with a good approximation, to those of the principal joint systems through the rock mass in this sector.

Below elevation 1850 m it is no more possible to see evident large rock masses preserved and traslated downwards: the slope turns out to be mainly formed by large size debris.

In the lower part of the large slope instability the major landslide deposits lays on moraines or roches moutonnees.

Methods of geomorphological data collection

The geomorphological survey of the Clot Brun large slope instability phenomenon started with the research and measurement of landslide-related landforms and characteristic surface deformations: trenches, fractures, en echelon fractures, scarps, counterslope scarps, stretched and closed depressions, elongated ridges.

Other natural kinematic indicators such as tilted and deformed trees have been coupled with damages and cracks on athropogenic structures.

Data about geometry, kinematics and state of activity has ben collected using standardized forms. In addition to height, width and lenght measures of each deformational structure, if possible, kinematic indicators has been interpreted as displacement vectors (dip, dip azimuth).

Geomorphological survey also took in account minor associated phenomena to the major landslides, such as debris-covered areas, detachment zones of rock wedges from major outcrops, inactive and active minor shallow landslides.

Applying geo-structural analysis methods, bedrock structural discontinuities (faults, joints) has been described. Rock masses has been analyzed and zonated on the base of geomechanical properties and

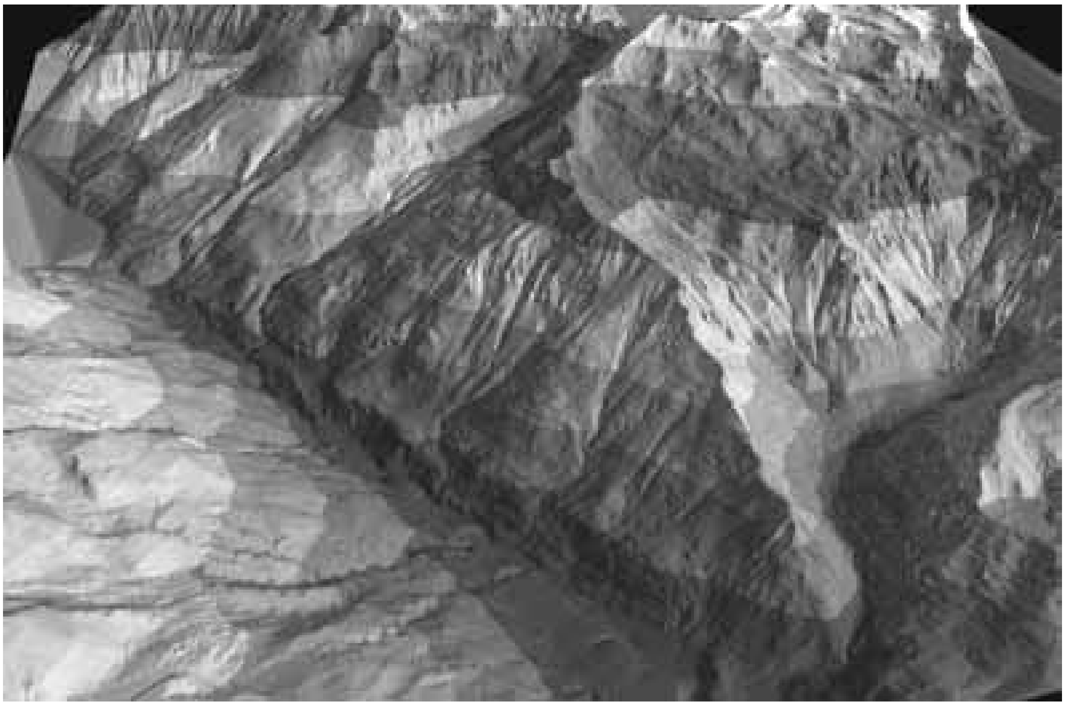

Figure 43 - DEM of the middle Susa Valley with Clot Brun large slope instability (central part of the image, left side of the valley).

"displacement degree" with respect to gravitational phenomena. An expeditious, field observation-based classification of rock quality has been applied, differentiating 5 classes: "intact" rock (few minor structural discontinuities), fractured rock (several closed structural discontinuities), "loosen" rock (open fractures), disjointed rock (very open fractures with rotated rock blocks), rock block accumulation (no more rock mass integrity).

Field data have been controlled and integrated through multi-temporal aerial photointerpretation. Bedrock outcrops, structural discontinuities, glacial, periglacial, torrential, slope landforms and deposits have been studied and mapped on a 1:10000 base, along Clot Brun large slope instability phenomenon and in sorrounding areas.

G.I.S. techniques for data analysis and interpretation

After field survey, photointerpretative intergration, data base structuring and storage of collected data, analysis and interpretations have been conducted through application of G.I.S. techniques. Distribution and attributes of geomorphological, structural and surface-deformation elements connected to the Clot Brun large-slope instability phenomenon have been used to draw a "Homogeneous Sectors Map". Kinematic indicators derived by surface-deformation elements have been used to draw a "Displacement evidences Map".

The homogeneous sectors have been individualized through geological and geomorphological interpretation connected to spatial analysis by ESRI ArcView software. In order to get qualitative and quantitative meaning for the sector's homogeneity, graphical elements of the GIS theme directly interacted with corrispective alphanumerical data.

"Displacement evidences Map" has been carried out through the selection of special deformational marker (trenches, opening fractures, damaged man-made structures, shifted bedrock outcrops, ...), the extrapolation of dimensional (geometry of the structure, kinematic vectors and displacement entity) and adimensional attributes (state of activity). A final classification of the kinematic meaning of different deformational elements has been proposed.

Rock fall hazard analysis

The procedure used for the evaluation of the hazard of collapses and rock fall involving about 15.000

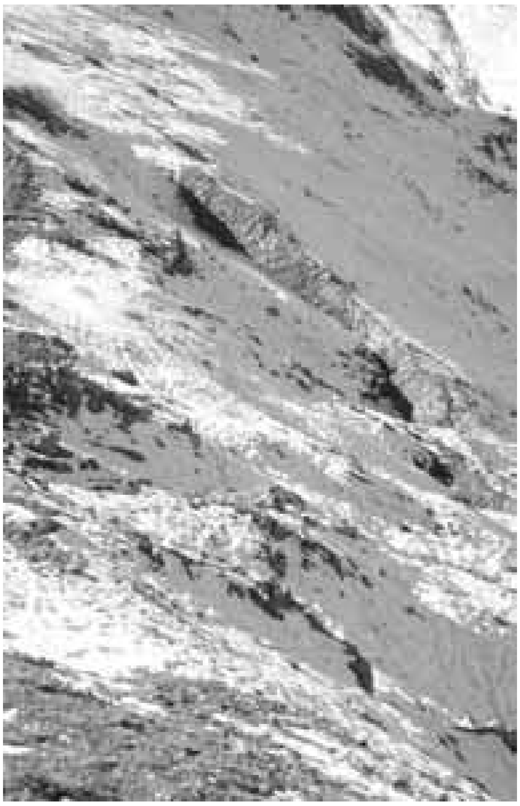

Figure 44 - Counter slope scarp of the upper part of the Clot Brun large slope instability.

mc comes from the Matterock method developed by the Sion CREALP (Switzerland); the probability of occurrence of the joints has been determined by a statistical function which considers the length of the tracks (T) and the spacing (L) of the discontinuities in a determinate area (observation window).
Discontinuities, their geometrical characteristics (spacing and length of the tracks) and the type of movements (kinematisms) have been identified by digital 3D remote sensing (using StereoView software) and subsequently verified through a short field trip.
The rocky walls have been subdivided into homogeneous structural areas on the base of the spacing and average length; subsequently with a GIS software, the probability of occurrence of the joints inside the observation window, corresponding to 25x25 m cells (grid), and the mean volumes of every movements have been evaluated.
The above described step has allowed to elaborate thematic maps concerning the probability of occurrence of the joints and hazard probability (P) of the movements, assuming that this latest is the product of the probability of occurrence (PO) and the magnitude (average volume - M).
The kinematic analysis, executed for movements of planar kind and upsetting (excluding the wedge mechanism less represented), has allowed to exclude, for every kinematism, the cells in which the movement is not possible. The map of the zones potentially unsettled has been obtained by sum of the various kinematisms.

Large slope hazard analysis

The evaluation of the hazard of the big alpine deep landslides is complex; the moving probability and their relative intensity depend on several variables as the activity state, the morphometry of the landslide, the triggering mechanisms etc.. The lack of information in order to identify and characterise more exhaustively the rupture surface of the moved mass has not allowed to evaluate the hazard through the use of deterministic methods. The hazard has been evaluated through a quick and easy-to-apply method using the information derived from the multidisciplinar study.
In synthesis it is assumed that the hazard (P) is the product between a propensity index to the movement (IP) of the landslide and the intensity, quantified by the average volume (VP) of the moved mass.

IP = FP1+FP2+FP3+SA = (GF+TD+TS+ST) +(HG+PE+LC) + (TD+TS+ST) + GA (2)

This calculation has been executed by GIS software turning the values of every level factor 1 and 3 into homogeneous areas and subsequently into 20x20 m grid.
The distribution of values identifies two zones to greater hazard. In conclusion, it is possible to affirm that the proposed method allows a quick evaluation of the large-slope instability hazard allowing the identifying of sectors characterized by differential landslide activity.

Acknowledgements

Thanks to:

- LUZENAC GROUP
- SCOPRIMIERA
- PROVINCIA DI TORINO – SERVIZIO DI PROTEZIONE CIVILE
- PROVINCIA DI TORINO – SERVIZIO DIFESA DEL SUOLO

- REGIONE PIEMONTE – SERVIZIO DI PROTEZIONE CIVILE
- COMUNE DI PRALI
- COMUNE DI PRAGELATO
- COMUNE DI CESANA
- LEICA
- SITAF
- FALZONI S.A.S.
- CITIEMME

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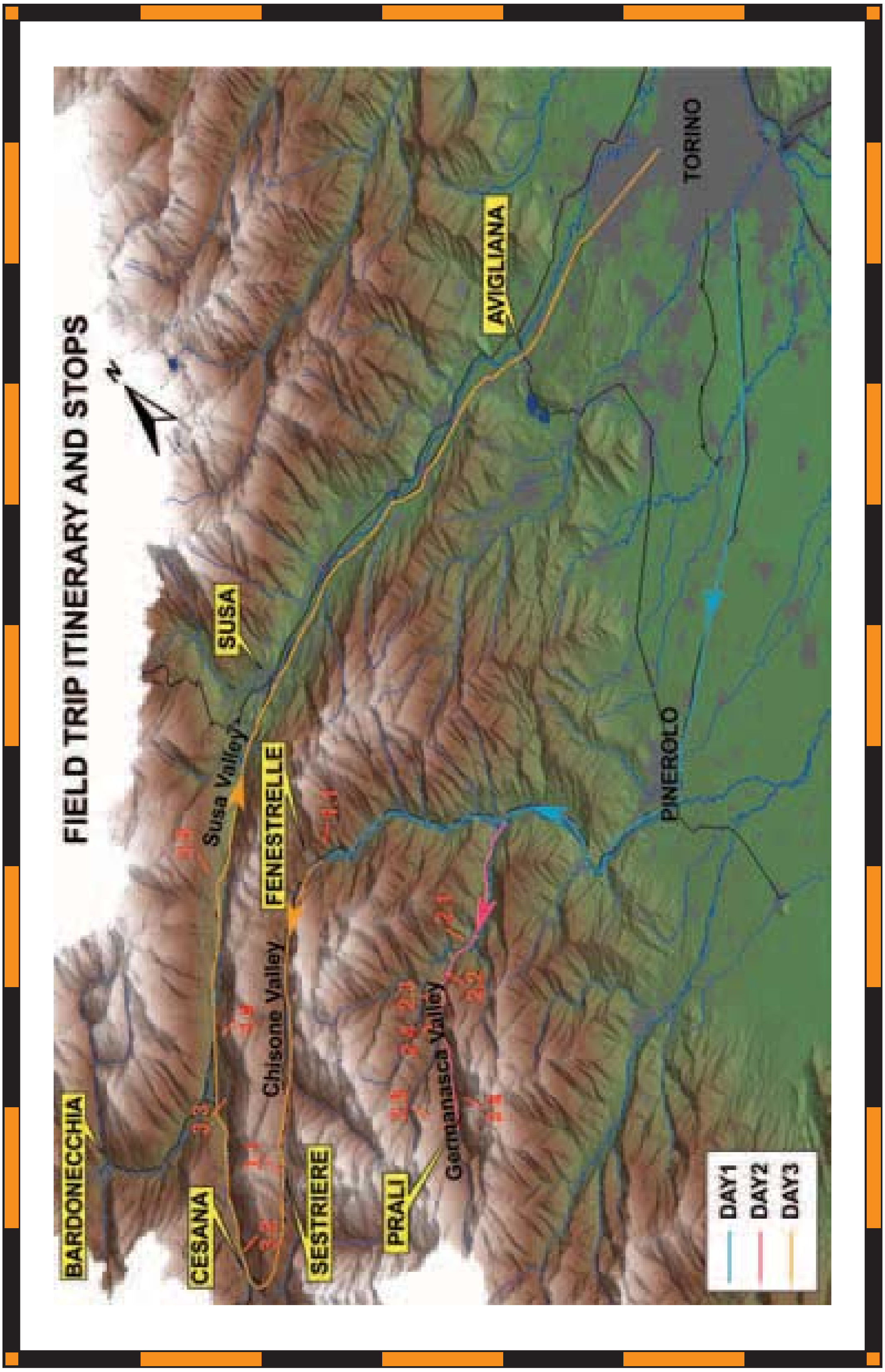
Back Cover:
Road map of Northwestern part of Torino Province marked by daily stops locations.

32nd INTERNATIONAL GEOLOGICAL CONGRESS

FIELD TRIP MAP



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