Volume n° 6 - from P55 to PW06

32nd INTERNATIONAL GEOLOGICAL CONGRESS

ALPINE-TYPE LAKES IN ITALY AND SWITZERLAND: GEOLOGY AND ENVIRONMENT

Leader: L. Vezzoli

Associate Leaders: F. Anselmetti, S. Bernasconi

Field Trip Guide Book - P55

Florence - Italy
August 20-28, 2004

Post-Congress **P55**

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Front Cover:
A view of the Bellagio Peninsula in the Lake Como

Leader: L.Vezzoli
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Introduction

Many deep lakes exist at the southern and northern slopes of the Alpine chain. These lakes share a number of geological, geomorphological and environmental features with lakes of glacial origin worldwide. Alpine-type lakes represent invaluable environmental resources, and are socially very important as drinking water supplies and for their tourist and recreational value. Investigations conducted on peri-alpine lakes over the last few decades have demonstrated that their sedimentary infill contain archives of the latest Quaternary climatic and environmental changes, including evidence for extreme hydrogeological events. In addition, they may be one of the best archives for the study of recent tectonic deformations, and for the stratigraphic record of paleoearthquakes in a region exposed to seismic hazard.

During this excursion we will visit two of these lakes on boat cruises: Lake Como in the south, and Lake Lucerne in the north of the Alps (Fig. A). The main goal of this field trip is to discuss the origin and evolution of the lakes, and to present some of the recent results of studies dealing with environmental, paleoclimatological and paleoseismological research. In addition, we will have the opportunity to examine some aspects of alpine geology and tectonics, and to visit some historical sites, all linked to the lake and its role in an alpine realm. We will also deal with engineering and environmental aspects of a renaturation project of the Reuss River delta, using the excavation products from the new railroad tunnel under the Mt. St. Gotthard.

The fieldtrip will thus cross the alpine edifice and link the southern and the northern side, providing a lacustrine perspective of this multi-faceted alpine environment.

Lake Como

Lake Como (or Lario) is located in Lombardia, Northern Italy, at an elevation of 198 m a.s.l., surrounded by steep mountain slopes up to ca. 2500 m a.s.l. high. It is the deepest lake in the Alps (-410 m), with an extension of 145 km^2, a volume of 23372 km^3, and a catchment area of 4508 km^2. This is obviously a strategic area from an economic point of view, because of both its unique cultural value and the presence of an inestimable water resource.

Lake Como is characterized by a longitudinal N-S trending: its drainage basin, which includes some of the most important Italian alpine valleys (Valtellina and Valchiavenna), corresponds to one of the major morphological pathways between Northern and Southern Europe. Due to this peculiar geomorphic setting, the Lake Como basin has been extremely sensitive to the climatic variations which have occurred during the last 20 ka. It can be regarded as a natural archive, containing the climatic and tectonic evolution of an environmentally-relevant piedmont area, and can be used as a tool for evaluating the pollution processes occurring in the entire catchment area. Besides, Lake Como represents a strategic water resource in one of the most populated and economically developed European countries. Therefore, Lake Como provides a unique insight into understanding the Holocene to Present rates and trends of physical processes, in a key area of the Alpine Chain, including erosion, transport, and sediment accumulation.

Figure A - General overview of the field itinerary.

Regional geologic setting

Lake Como is geologically located in the Central Alpine chain. The most significant structural element in this area is represented by the Insubric line, a fault trending E-W which represent the Tethys oceanic subduction plane, and which has experienced transcurrent Alpine movements. The Insubric line cuts Lake Como's northern edge, and divides the axial zone of the Alpine Chain, formed by the Austroalpine and Pennidic units, from the Southern Alpine basement and Carboniferous-Mesozoic cover. The Southern Alpine zone is an orogenic belt with south-verging and E-W trending overthrusts. Its crystalline basement consists of paragneiss and subordinate orthogneiss and amphibolites of Variscan age (Spalla et al., 2002). The Variscan rocks are non-conformably overlain by Upper Carboniferous clastic sediments, followed by Lower Permian ryodacitic volcanics, locally interfingering with lake sediments. During Late Permian, the Verrucano Lombardo alluvial red sandstones and conglomerates were deposited. The first marine transgression in the Lake Como area is Ladinian in age and represented by the peri-tidal and reef formation of the Dolomia di S. Salvatore. The thickness of the whole Permian-Triassic succession ranges from less than 50 m in the area west of Lake Como, to more than 2000 m in the easternmost area of the Southern Alps. The widespread and thickest outcropping unit cover of the Lake Como area is the Calcare di Moltrasio, Liassic in age, represented by monotonous dark grey limestones, siliceous limestones, and marly limestones up to 3000 m in thickness. This unit fills a strongly subsiding rift-basin (M. Generoso basin) controlled by the Lugano normal-fault (Bernoulli, 1964). In the middle part of the western Lake Como area, near Menaggio, the Lugano fault, reactivated in alpine times as the Lugano-M. Grona-Val Grande fault, marks the contact between the Southern Alps Variscan basement, and the SW-SSW general dipping sedimentary cover (Bertotti, 1991). In the eastern side of Lake Como, near Bellano, the M. Grona-Val Grande line becomes intracrystalline. At Lake Como's southern end, several sections of a 2-3 km thick sedimentary wedge of coarse clastic deposits of Oligocene-Miocene age crops out (Gonfolite Group). Thanks to the zigzag pattern of the cruise, during the trip on the boat it will be very easy to recognize the fact that the lake, along the branch from Como to the village of Menaggio, has a non-linear shape. This part of Lario can be in fact subdivided into four sections, each characterized by different trends and physical properties: the shallow Como basin, N-S trending; the basin between Moltrasio and Laglio, with a medium depth (-200 m), ca. E-W trending; the Argegno basin, where the lake reaches its maximum depth (-410 m); and the section between Argegno and Menaggio, which is characterized by the presence of a sill in the Eastern part that isolates this branch from the rest of the lake.

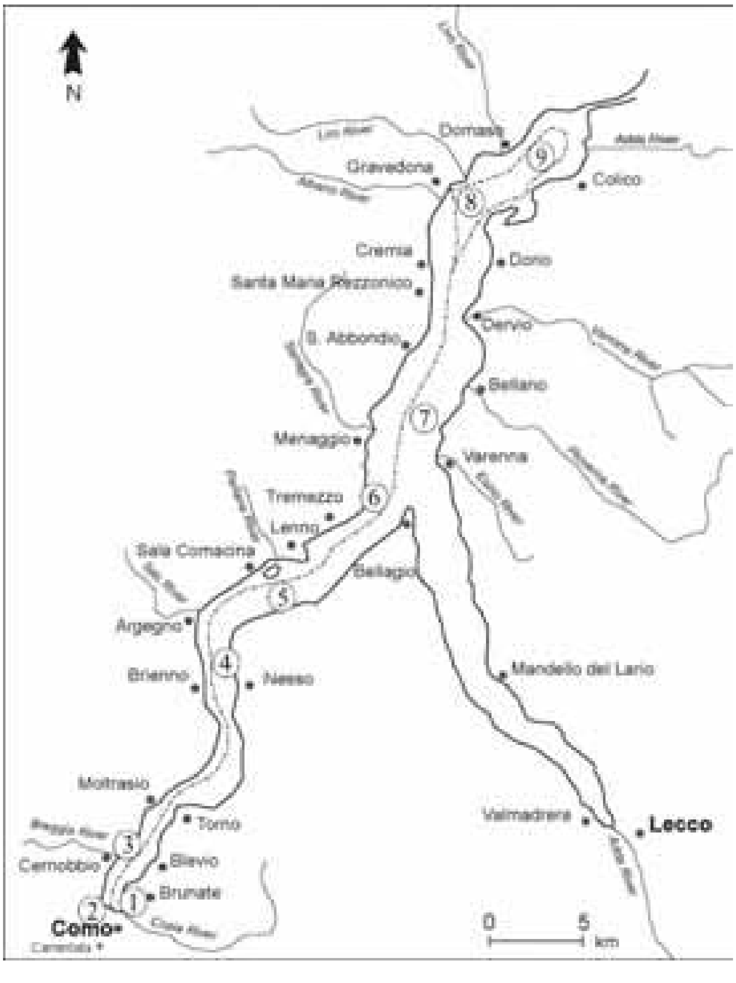


Figure B - Overview of the stops in the Lake Como region.

FERROVIA-FUNICOLARE
COMO-BRUNATE
APERTURA
11 NOVEMBRE 1894
ORARIO
PARTENZE DA COMO E DA BRUNATE
TARIFFA PROVVISORIA
Da COMO a BRUNATE L. 1.=
Da BRUNATE a COMO =.50

Figure 1.1 - 1894 funicular inaugural playbill.

Field itinerary

Days 1 and 2 will be devoted to the visit of Brunate and Como, and to the boat cruise of the SW and N branches of the Lario (Fig. B).

DAY 1

arrive at Como town in the early afternoon.

Stop 1.1:

Brunate, Como.

This field trip start from Piazza de Gasperi in Como, travelling by funicular railway to Brunate. , This striking funicular was inaugurated in 1894 (Fig. 1.1), has a maximum steepness of 55%, and runs straight up the hill slope East of the Como urban area (Fig. 1.2).

Looking down from the balcony placed at the arrival of the Brunate cable car, it is possible to observe Como town and part of Lake Como (Fig. 1.3), which lies in a downstream-bifurcated glacial trough, sited across the Central Alps, and was intensely modelled by an ice tongue up to ca. 2 km thick during the Last Glacial Maximum (LGM; Fig. 1.4).

The present geomorphology of the area is essentially the result of the erosive action of the Quaternary glaciers. The steep profile of the mountain slopes is locally carved to form the so-called "glacial shoulders". The Brunate city center is a probable glacial shoulder: this consideration is supported by the presence of glacial deposits dominating the Mesozoic limestone bedrock.

The Como urban area is located at the S edge of the W branch of the lacustrine basin, that was filled by glacial deposits during the LGM and subsequent late glacial climatic fluctuations (Fig. 1.5A). During the early deglaciation phase, the Como area hosted a proglacial lake (Fig. 1.5B),

Figure 1.2 - The Como - Brunate funicular.

Figure 1.3 - Panoramic view of Como town, from the Brunate funicular top station.

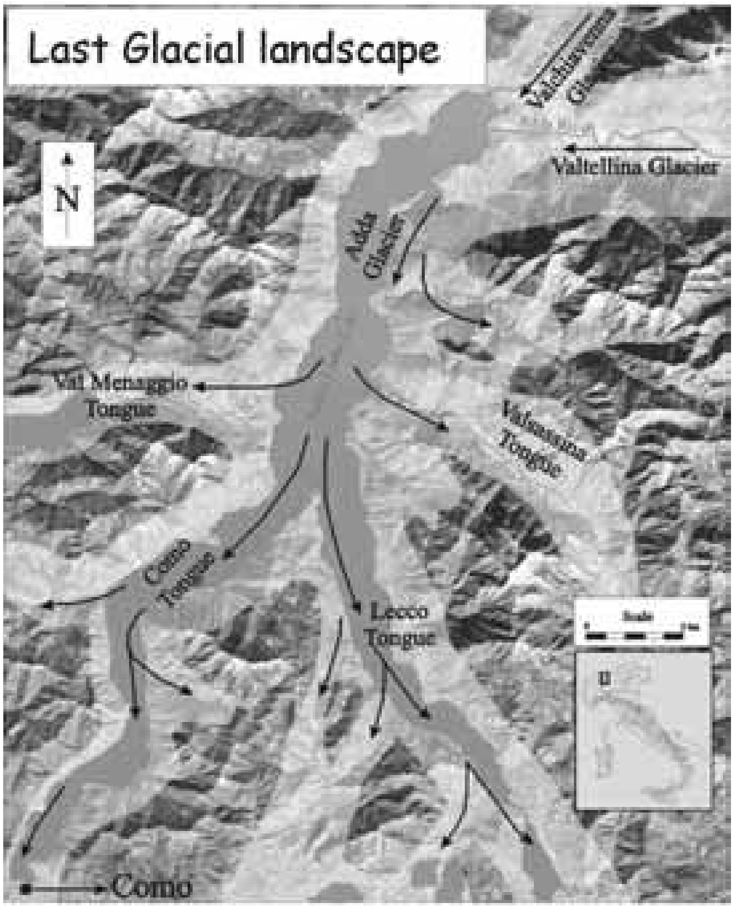


Figure 1.4 - Landscape of the Lario region during the Last Glacial Maximum.

situated between the forehead of the glacier in retirement, and the Camerlata threshold (270 m a.s.l.). On the bottom of this lake were deposited clays mixed to dropstones, i.e. subangular debris, deriving from the melting iceberg from the forehead of the glacier. The proglacial lake drainage was to the south. With the progressive ice melting, the lake level in the Como area dropped to ca. 220 - 210 m a.s.l., and the drainage system in the surroundings of the Como Plain was reversed (Fig. 1.5C). At this stage, lacustrine terraces formed near the St. Abbondio site (Fig. 1.6). Drillings at this site allowed for the sampling of silty sand levels rich in organic matter and wood fragments of Larix and Picea. Radiocarbon dating of these materials constrain the deposition of the St. Abbondio lake sediments to between 13230 +/- 120 C^{14} yr B.P. (Centre for Isotope Research, University of Gröningen; Comerci et al., 2003), and 11730 +/- 180 yr C^{14} B.P. (Castelletti & Orombelli, 1986). Then, the lake level dropped progressively to the actual one (199 m a.s.l.). This means that at least from this period the lake level was similar to the actual one: the plain where the present day Como town rises was a marsh, slowly filled up by alluvial sedimentation during

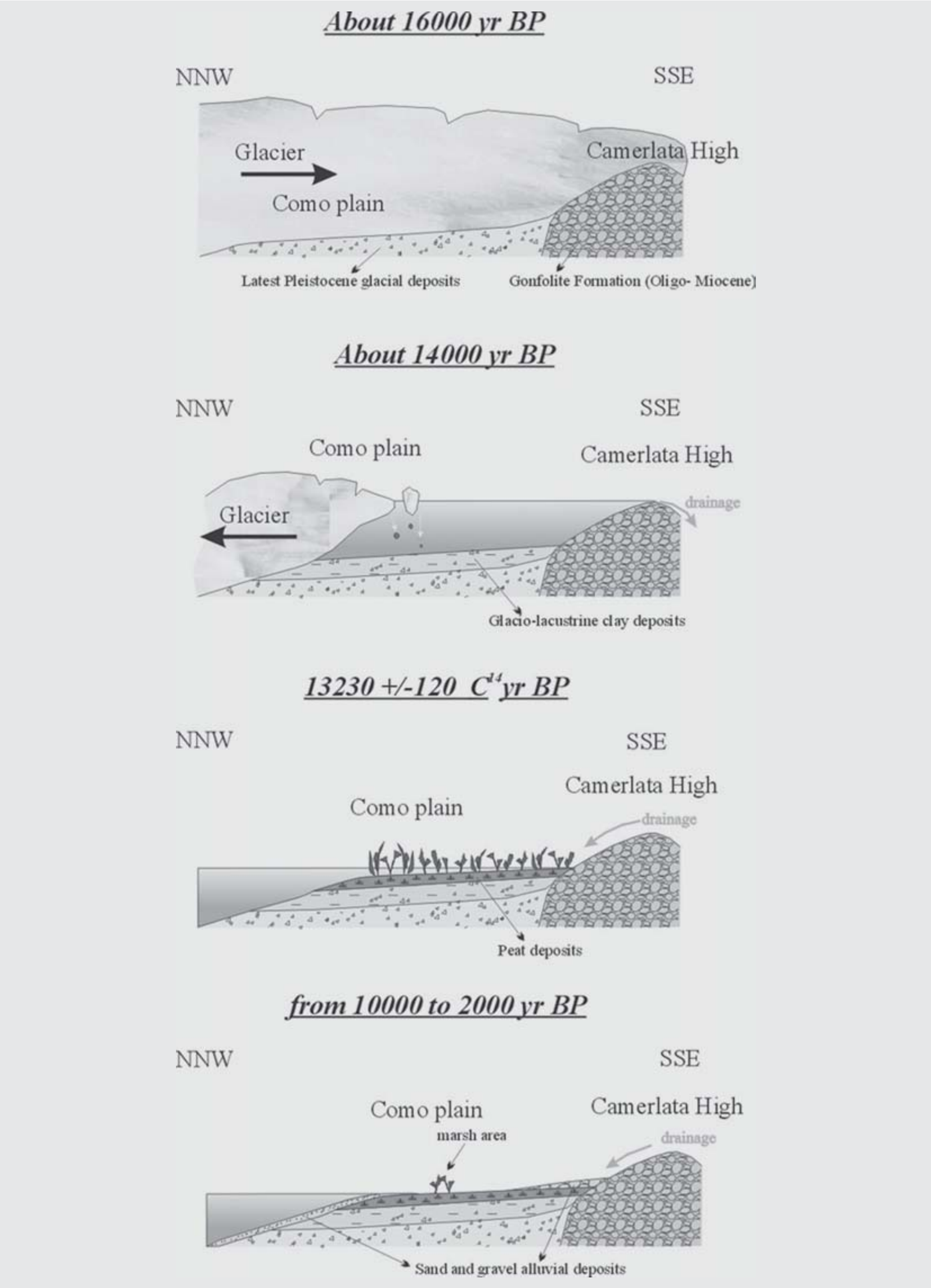


Figure 1.5 - Como plain paleoenvironmental evolution since the Last Glacial Maximum.

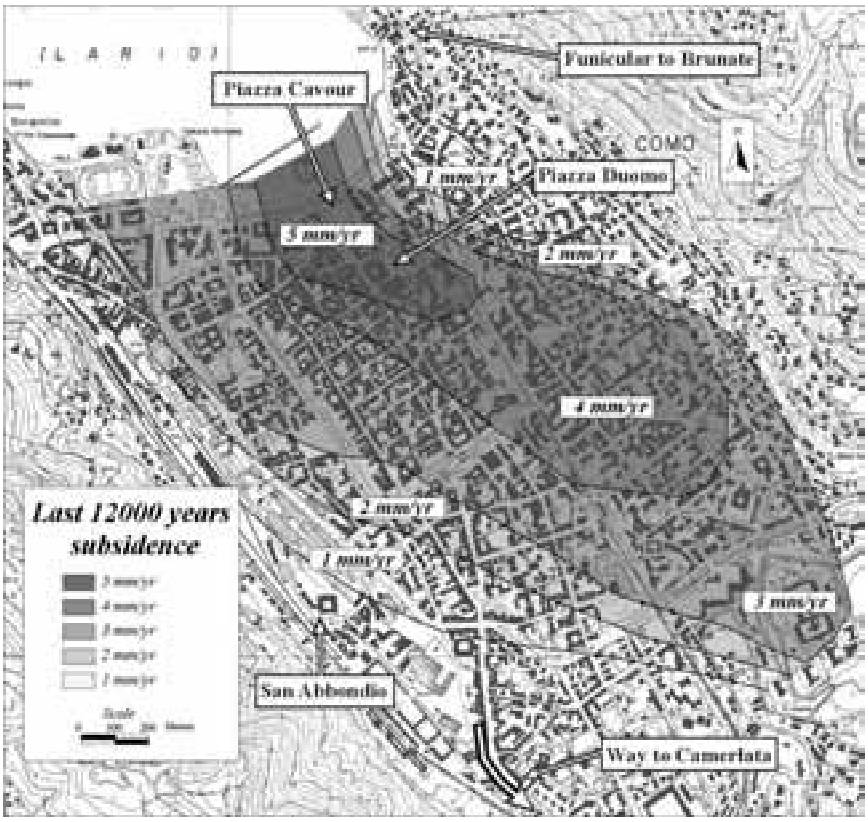


Figure 1.6 - Como Plain Holocene subsidence map. The subsidence increases in correspondence to the thickening of peat deposits.

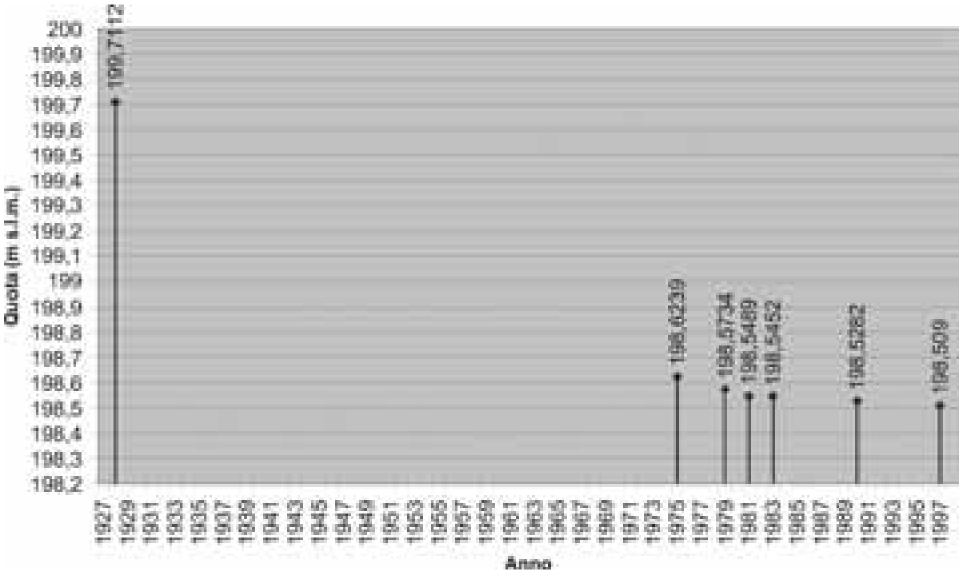


Figure 1.7 - Piazza Cavour topographic measurements from 1928 to 1997.

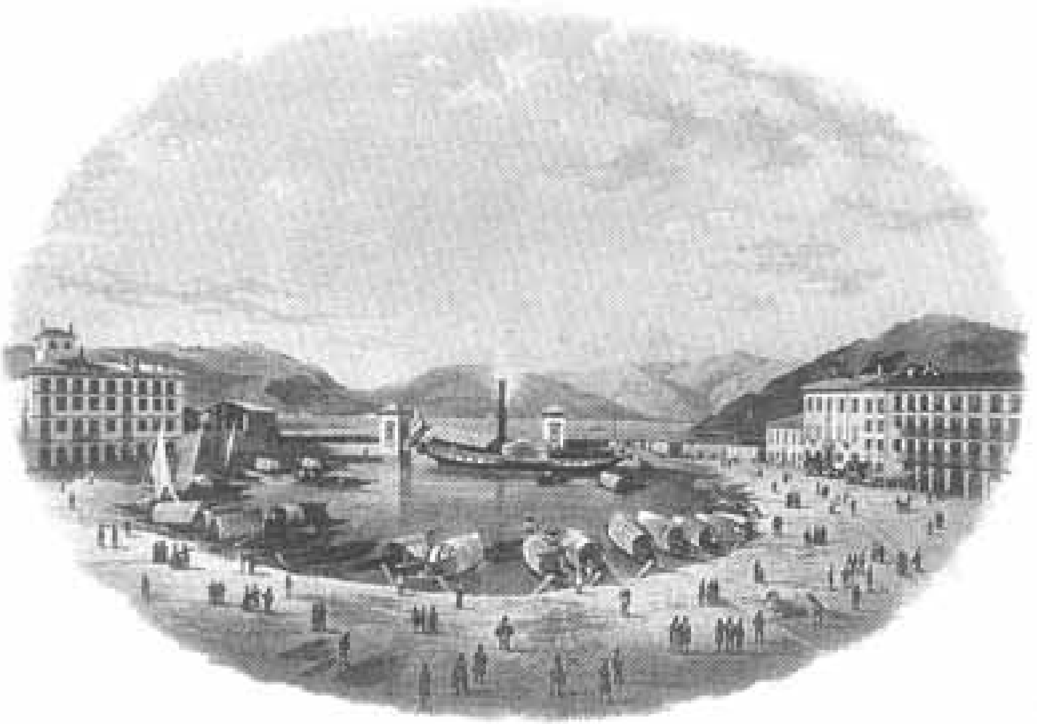


Figure 1.8 - Como harbour in 1846, where Piazza Cavour is now located.

Figure 1.9 - The Brunate hill and the Como funicular station during the 1910 lake flood.

Figure 1.10 - Piazza Cavour during the 2002, 27 November lake flood; the arrow shows the location of the label that was subsequently placed on the corner of the building, marking the level reached by the 2002 flood.

Figure 1.11 - 1888 lake flood in Piazza Duomo.

the Holocene. The area in the proximity of the lakeshore remained a uninhabited marshy zone up to the reclamation performed by the Roman Republic, which started from 59 B.C. (Fig. 1.5C and 1.5D).

In the Como urban area, remarkable phenomena of ground subsidence have been recorded over the past few decades. Maximum values of 20 - 40 cm up to ca. 1 m of ground lowering were measured in the districts close to the lakeshore from 1955 to 1975. In the last 20 years, subsidence rates in the same districts decelerated to mean values of 3 to 4 mm/yr, following the ban of extraction of deep ground water, indiscriminately exploited immediately after the Second World War. These values represent the long-term “natural” trend, and therefore are to be expected for the near future. The preliminary results of our study show that ca. 5 mm/yr is the subsidence value over the last ca. 12,000 years in the central part of the town (Fig. 1.6; Comerci et al., 2003). The human component seems therefore to have been relevant only during the named 1955-1975 critical phase of ground subsidence.

Moreover the still active subsidence of Piazza Cavour (2 cm between 1990 and 1997), shown in Fig. 1.7, is presumably attributable to the consolidation of the debris deliberately accumulated to fill the old harbour (Fig. 1.8).

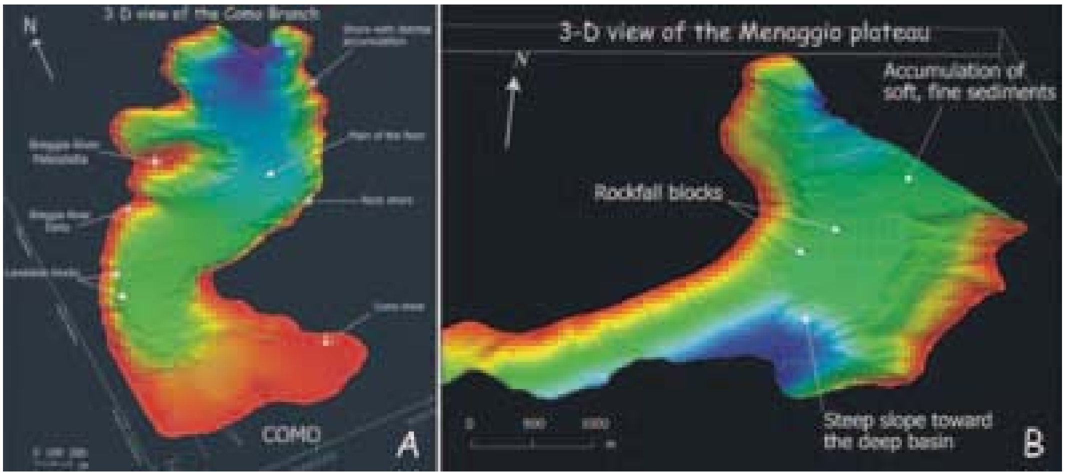


Figure 2.1/A - Three dimensional view of the Como branch, obtained by a Multibeam (Simrad EM 3000) mapping system; 2.1/B - The plateau area between the villages of Bellagio, Tremezzo, and Menaggio (Fanetti et al., 2003).

Stop 1.2:

the town of Como.

From Brunate (Fig. 1.9), the trip will continue the discovery of old Como towards the "Città Murata", the historical part of the town surrounded by defensive Roman and Medieval walls. Walking along the Lungo Lario Trieste we reach Piazza Cavour where a sign in the NE square corner, on the wall of a palace, indicates the maximum lake level during the July 17, 1987, and November 27, 2002, lake floods (Fig. 1.10).

Through Via Plinio we reach Piazza Duomo, also flooded several times in the last century (Fig. 1.11). The building of the Duomo began in 1397. It was finished only in 1770. The Broletto, near the Duomo building, is the ancient site of the Como Medieval Communes, and was built in 1215.

Figure 2.2 - Como Lake is characterized by the presence of Villas of outstanding beauty. From the top, A) Villa Olmo in Como, B) Villa Erba and C) Villa d'Este in Cernobbio.

DAY 2

A boat will take us on a round trip from Como to Gravedona village, in the northern part of the Lario lake.

Stop 2.1:

Cernobbio-Breggia delta.

The Como basin is the closed branch of the lake, does not have an outflow, and contributes to the water balance of the lake with two major rivers (Breggia River and Cosia River). The bathymetry in front of the town of Como (Fig. 2.1/A), is characterized by a maximum depth of about –50 m, and defines a shallow shoal composed of lacustrine and glacio-lacustrine sediments and overlaying unconsolidated organic-rich sediments transported by the Cosia River. The western basin slope, in front of Cernobbio, shows a few hundred meters wide fan-delta body, representing the paleo-delta of the Breggia River, which has developed since tardiglacial time. In historical times, the Breggia River channel has shifted from the north to the south of its alluvial deposit. A smaller fan-delta body at the southern valley outlet corresponds to the present day Breggia River mouth.

On the way, it is possible to see some beautiful and famous Villas (Fig. 2.2), such as:

Villa Olmo, that, according to Plinio il Vecchio (Pliny the Elder), is located on the ruins of Caninio Rufo's Roman patrician house. Its name is related to the presence of a centuries-old elm tree, and it was constructed between 1785 and 1810 for the marquis Innocenzo Odescalchi by the architect Simone Cantoni. The coat of arms of the Visconti family, who were the owners until Como town hall became the new holder can be seen on the roof pediment .

Villa Erba (Cernobbio) and its age-old park are located on the area of the Breggia River paleodelta. It is directly on the lake and was constructed by Luigi Erba, brother of Carlo, the founder of the homonymous pharmaceutical industry. The villa was built between 1894 and 1898, in the manneristic style. It was the much loved residence of the movie director, Luchino Visconti, but nowadays it's used as a conference hall.

Villa d'Este (Cernobbio): In 1568 Tolomeo Gallio, the Cardinal of Como, built a Villa named "Garrovo" as his private residence, reclaiming the impassable land. It was owned in succession by a ballerina and a Napoleonic General, a Queen without a crown, who renamed it Villa d'Este, a Russian Empress, and a minor aristocrat. In 1873 it was transformed into a luxury hotel.

Figure 2.3 - Some of the wonderful residences of Lake Como can only be reached by the lake, such as the Villa Pliniana, built over a karstic intermittent spring.

Stop 2.2:

Moltrasio-Laglio basin and Villa Pliniana (Fig. 2.3).

The Moltrasio-Laglio basin is characterized by an average depth of -200 m. This section is oriented E-W, and the depth increases towards the village of Laglio. Some E-W trending compressional deformations are present, such as folds and small reverse faults, induced by the gravity instability of the young loose sediments present on the slope. From the sedimentary point of view, this area is separated from the northern one by a break in slope, because the floor becomes suddenly much steeper moving northwards.

On the east coast, it is possible to see an historical residence, the Villa Pliniana. This name comes from an intermittent karst spring located close to the villa and narrated by both Plinio il Vecchio and Plinio il Giovane (Pliny the Elder and Pliny the Younger), who were born in the first century A.D. in Como, and were writers and officers of the Roman Empire. The edifice dates back to the second half of the XVIth century, when it was built by Giovanni Anguissola, governor of Como. This Villa is related to one of the most romantic memories: the prince Emilio Barbiano of Belgioioso enjoyed an eight-year long overwhelming love affair with Anna Berthier, princess of Malpaga, and the Duke of Plaisance's wife. There were many

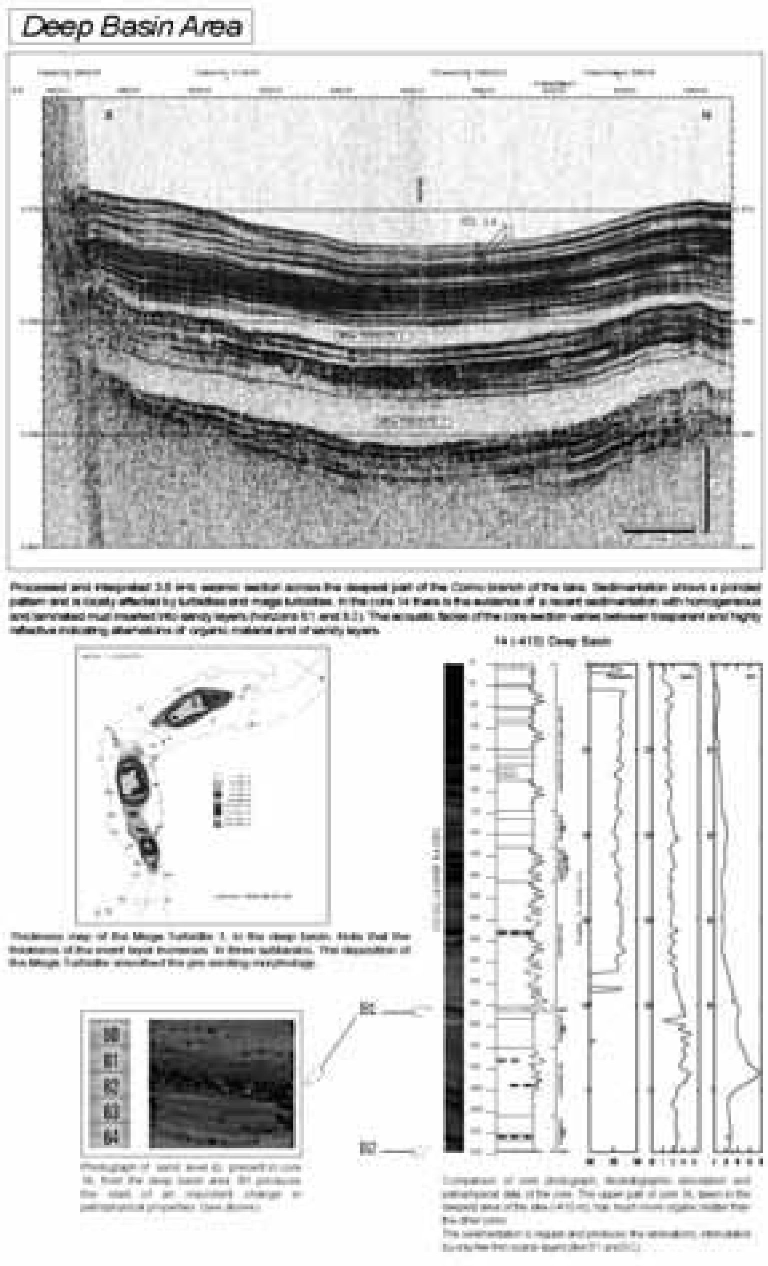


Figure 2.4 - Argegno basin, data and interpretation from the 3.5 kHz high-resolution seismic study and coring campaign of the lake concentrated on the Como branch (Fanetti et al., 2003).

famous guests: rulers and kings such as Giuseppe II and Napoleon; musicians such as Rossini and Bellini; poets and writers such as Byron, Foscolo, and Fogazzaro, who found there inspiration for his novel Malombra. Nowadays it belongs to the Pliny Academy.

Stop 2.3:

Argegno

The Argegno basin is the deepest basin of the lake, reaching a maximum depth of -410 m (212 m below sea level). The valley that hosts the lake here is quite narrow, with very steep and regular slopes defining a V shaped transversal profile (Finckh, 1978; Cita et al., 1990). This very deep basin is filled with onlap sedimentation, and is characterized by the presence of mega-turbidite events (Fig. 2.4), showing that the sedimentation was driven by density currents (Fanetti et al., 2003). As clearly illustrated in Figure 2.4, the two mega-turbidites in the first 50 m do not have a regular thickness. In fact, they show the presence of two/three different depocenters all along the Como branch. Their volume is quite large (in the order of $10*10^8$ m^3), and according to their distribution, it is possible to say that the source area is located at the northern tip of the Como branch, near Bellagio. The analyses of some short cores (maximum length of 165 cm), show evidence of recent sedimentation, with homogeneous and laminated mud, intercalated by turbidites. The acoustic facies of the cores varies between transparent and highly reflective, indicating an alternation of organic matter-rich and sandy levels.

Figure 2.5 - The Island Comacina is the only isle of the lake. It is a portion of land isolated from the slope, and therefore was preserved from the erosion activity of the glaciers.

^{137}Cs and ^{210}Pbdating of core CO-14, indicate a sedimentation rate of 0.74 cm/yr. This sedimentation rate is the higher of the whole Como branch, due to both the position of the sediment sources, and the morphology of the basin.

Stop 2.4:

Comacina Island

The lake's only island, *Isola Comacina (Fig. 2.5),* lies opposite the village of Sala Comacina, whose name clearly sums up the status and position of this attractive village, lying on the western bank of the lake. It is a tiny square of wooded ground, with a history that is much longer that its 2 km perimeter.

Today, the island is one of the most important archaeological areas in Lombardy. It is known as the "medieval Pompei" of this area. There you can see the fourteenth century Church of San Giovanni, and the remains of the little Church of Sant'Eufemia which dates back to the seventh century and was later rebuilt in the eleventh century. Every year in June, the festival of Saint John takes place to commemorate the destruction of the island by the *Comaschi* in 1169 as a punishment for its alliance with Milan during the ten-year war (1118-1127).

On the top of the Dosso di Lavedo, just before the enchanting village of Lenno, there is the Villa Balbianello (Fig. 2.6). Built at the end of the eighteenth century for Cardinal Angelo Maria Durini, this Villa has one of the most enchanting views on the lake and surrounding hills. It had many owners throughout the centuries, when finally it was completely renovated in the Seventies by Guido Monzino, who enriched it with an incredible collection of beautiful works of art (such as Chinese vases). The Villa is now under the artistic protection of the F.A.I. (Italian Environmental Foundation).

Figure 2.6 - Along the western shore of the lak,e it is possible to see some pearls of Italian architecture. The Balbianello Villa, and its botanic garden, is one of the most beautiful residences in the area.

Stop 2.5:

Bellagio

Bellagio is located at the northern tip of the Como branch, that is physically separated from the rest

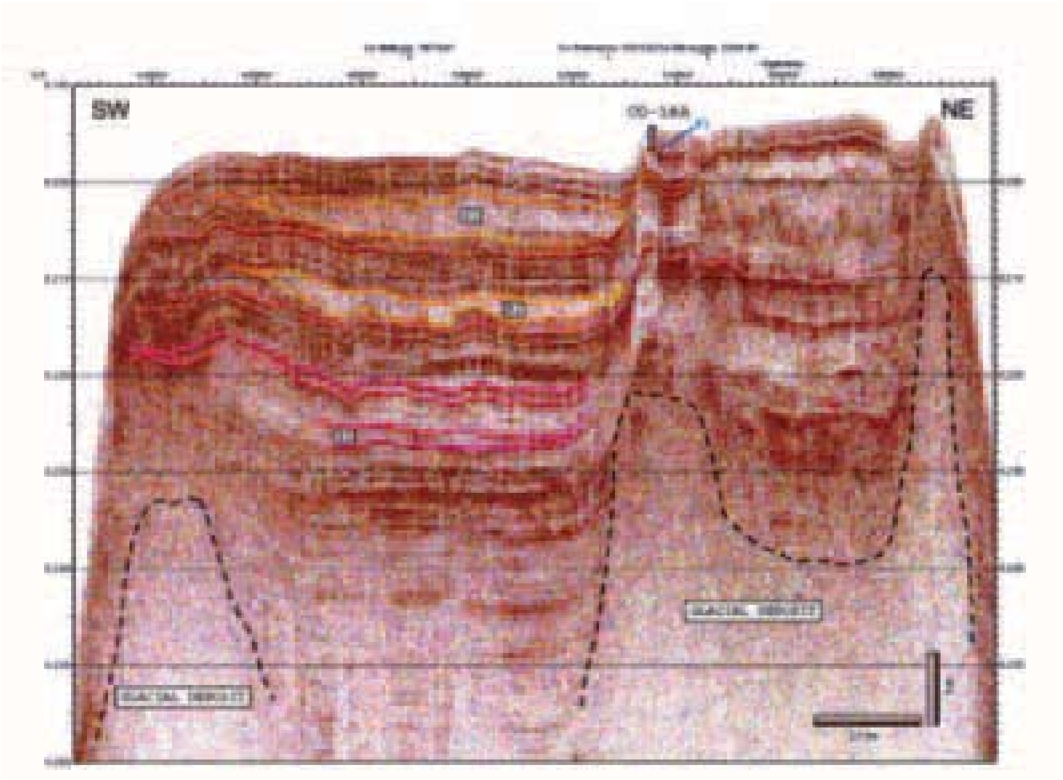


Figure 2.7 - Processed and interpreted 3.5 kHz seismic section across the plateau between Menaggio and Bellagio.

of Lario lake by a threshold, composed of an accumulation of soft sediments. This area, named "plateau" in Fig. 2.1/B, is characterized by prominent late-glacial depositional structures that influenced the subsequent sedimentation, as clearly illustrated by the high-resolution seismic profiles shown in Fig. 2.7. They are interpreted as delta moraines built during the last deglaciation, and are the only ones preserved on the Lario lake floor. Their conservation is probably due to their special morphological position: in fact the crucial area of the Bellagio junction is somehow sheltered from later erosional processes.

The sedimentation over the delta moraines is organized as follows: in a first phase, the deepest part of the glacial structures is covered by onlap sedimentation and some slumps, while the second phase is characterized by a draping sedimentation. From the analyses of some cores, it has been discovered that the most recent depositional processes are characterized by fine laminated mud, with only some rare sandy events. The isotope analyses conducted on a plateau core (CO-18A), indicate that this area is characterized by significant slope instability. The upper part of the core is missing, due to a slump event also recognized on the multibeam data. The morphology of the plateau (Fig.2.1/B), its position, and the high instability of the local sediments, suggest that this area is the best candidate as a source for the mega-turbidites preserved in the deepest sectors of the basin.

On the West coast, it is possible to have a spectacular view of Villa Carlotta (Fig. 2.8), with the beautiful house, staircases, and garden in the Italian style, built by Marquis Clerici in the XVIII century, and partially modified by Count Sommariva, according to the neoclassical style. The Milanese Marquis Giorgio Clerici began the building of the Villa in 1690.

On the East side, Bellagio, the pearl of Lake Como, includes one of the most well-known and prestigious hotels in the world: Villa Serbelloni (Fig. 2.8). In 1872, the Villa, which is in pure neo-classical style, was sold, and since then, it has formed the central nucleus of the Grand Hotel Villa Serbelloni, which was opened in 1873. Its interior reflects the good taste of the wealthy nobility of the time. Walls and ceilings

Figure 2.8 - The Villas Serbelloni(A) and Carlotta (B).

are adorned with frescoes and painted mythological scenes, gilded frames, festoons, temples, putti, flamingos, and often in Pompeian reds.

Stop 2.6:

Varenna.

Travelling to the northern part of the lake, the Conca di Menaggio can be seen on the right side. The observation of the Grona Line (the mountain which closes the Conca di Menaggio to the North is the Monte Grona) is of particular interest (Fig. 2.9). This important tectonic lineament brings the crystalline basement to the north into contact with Norian rocks in the south ("Dolomie di S.Salvatore" Formation). Westwards, this line is truncated by the Lugano Fault, and towards the lake shore, by other minor N-trending faults.

The Musso village lies in a little inlet on the west side of the lake, at the foot of the peak named "Sasso di Musso" ("Rock of Musso"), which is a vertical lens of Paleozoic compact marble, embedded in gneiss and schists. Worth seeing are the ruins of the castle of Gian Giacomo De' Medici (called Medeghino), near the old marble quarry (Fig.2.10), that was mined from 1800 until 1970.

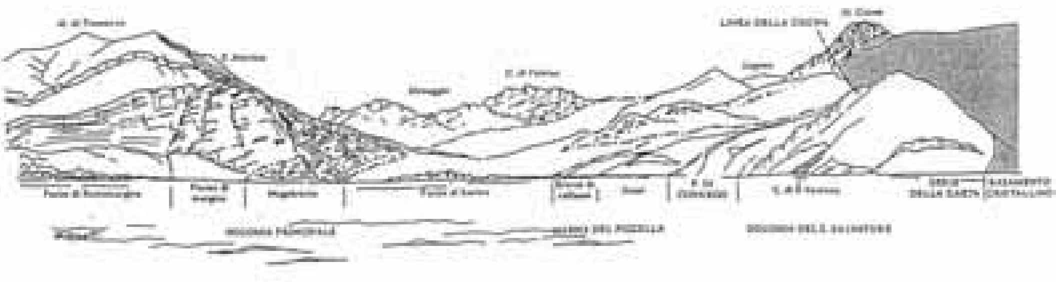


Figure 2.9 - View of the Menaggio valley, showing the Grona Line.

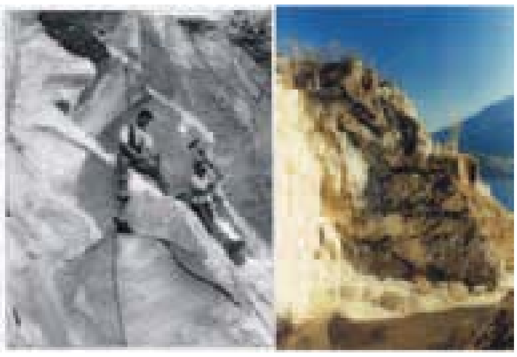


Figure 2.10 - A historical picture of the mine and the Castle of Musso ruins, rising straight from the marble quarry.

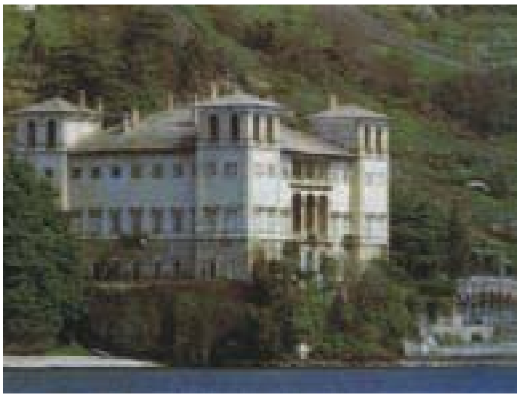


Figure 2.11 - The National monument, Palazzo Gallio, pride of the Gravedona local administration, is now the head office of the Comunità Montana.

Stop 2.7:

The Dongo and Gravedona gravel deltas, and the beautiful Palazzo Gallio

The northern part of the lake hosts several beautiful examples of late glacial to Holocene gravel deltas. In particular, on the West coast it is possible to observe the two coalescent gravel deltas of Dongo and Gravedona, formed by the alluvial deposits of the Albano and Livo Rivers, respectively. The two gravel deltas are clearly terraced. The old part of the Dongo and Gravedona villages is built on the upper terrace, which was clearly related to a Early Holocene lake level, several meters higher than the present day 198 m a.s.l.

Palazzo Gallio, the impressive construction which dominates the town of Gravedona, was built onto a jutting and rocky spit, between the mountains and the lake (Fig. 2.11). The magnificent dwelling place was ordered in 1586 by Cardinal Tolomeo Gallio, Secretary of State at the service of the papal throne. Having been appointed a few years earlier by the county of the Tre Pievi, Gravedona, Sorico, and Dongo, he assigned the realization of the building to Pellegrino Tibaldi, the architect of Cardinal Carlo Borromeo. However the building work was completed after 1607, the year of Cardinal Gallio's death. The mansion was left to his nephews, Dukes of Alvito, but it never enjoyed a splendid life. It was used by the French and the Spanish as a hospital until the early 1800s, when it passed into private hands. Today the building belongs to the Comunità Montana Alto Lario Occidentale, and is a national monument, the pride of the people of Gravedona, and today is also the location of the Insubria UniversityLimnogeological Lab.

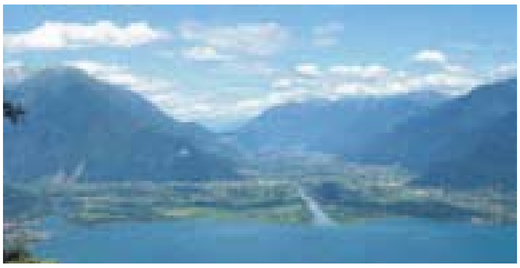


Figure 2.12 - An overview of the Adda River delta area at the beginning of Lario Lake. In the background, the Valtellina valley can be seen, and on the left, the end of the Valchiavenna valley.

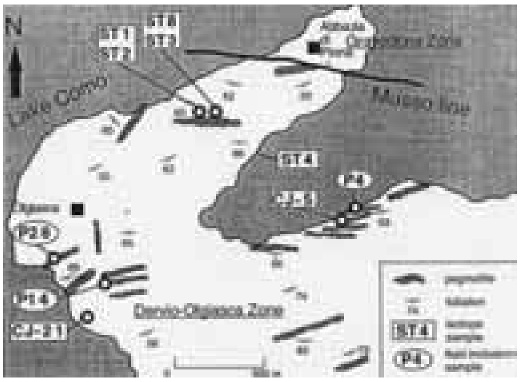


Figure 2.13 - Geological map of the Piona area, in the northern sector of lake Como (from Sanders et al., 1996).

Stop 2.8:

Colico

The northern part of the lake catchment includes the Valtellina and Valchiavenna Valleys (Fig. 2.12),

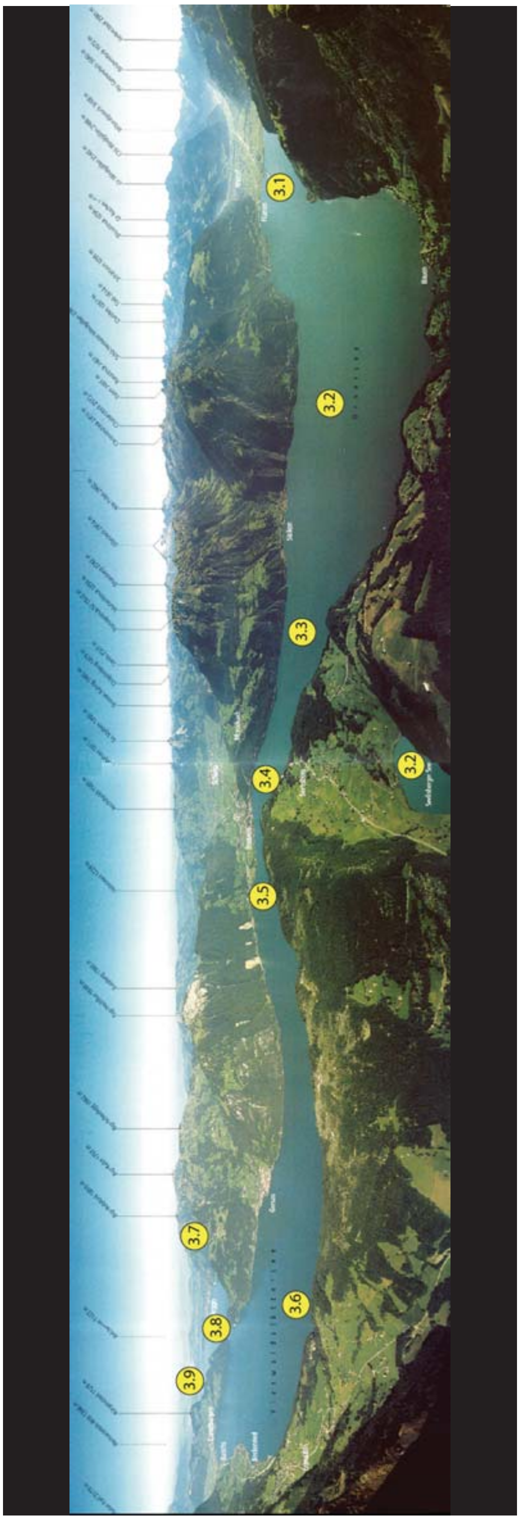


Figure 3.1 - Aerial panoramic view of Lake Lucerne with planned stops of day 3.

carved into the metamorphic basement. The most relevant sedimentary input to the Lario comes from the Valtellina by the Adda River, while the deposits transported by the Mera River from Valchiavenna are mostly trapped in a little lake located just north of Colico, Lake Novate-Mezzola. The Adda delta is characterized by the presence of the typical accumulation and erosive features, very clearly in the morphobathymetric map.

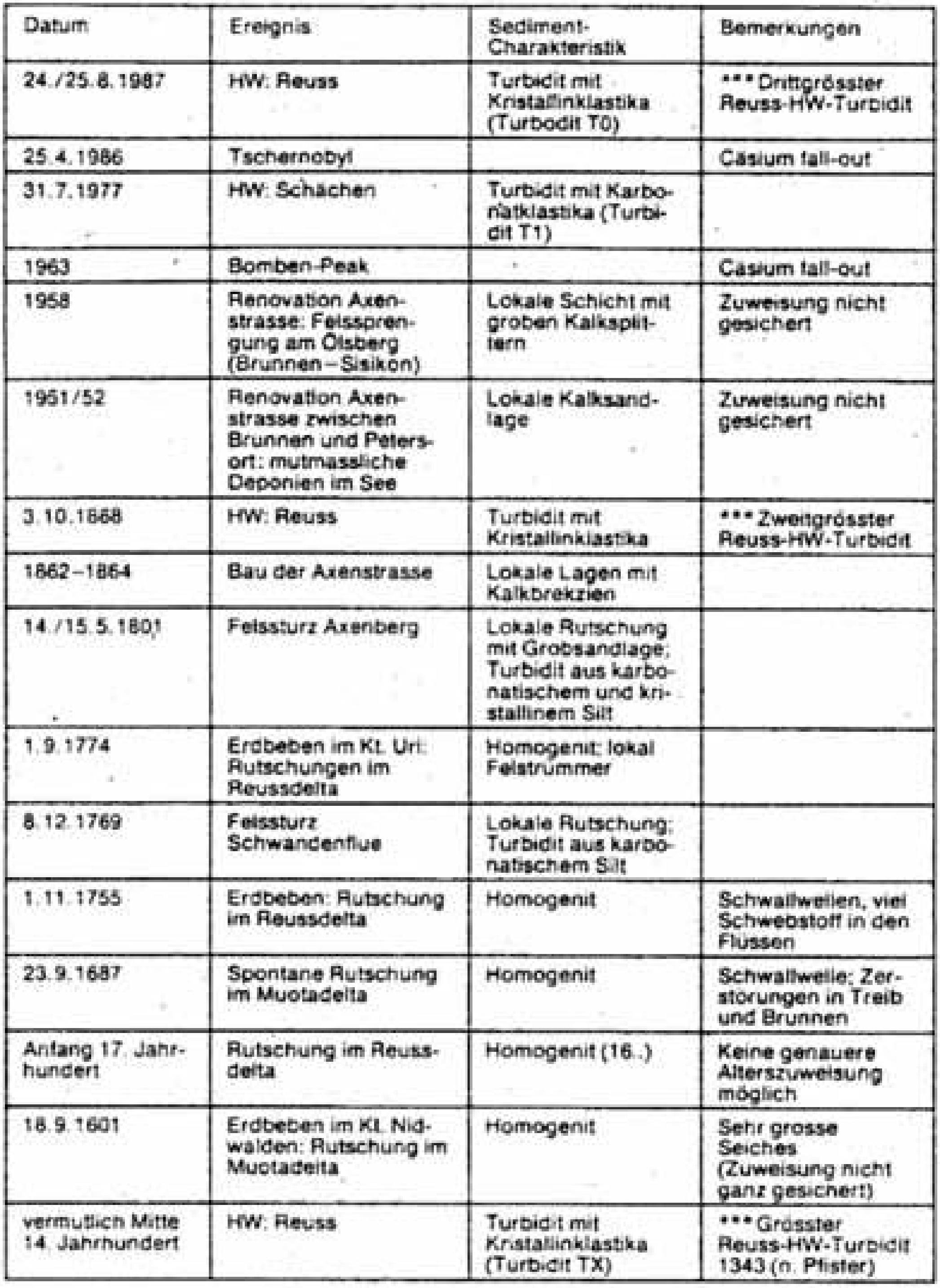
The Piona Peninsula area is quite famous, because of the presence of a swarm of about 30 pegmatitic dykes (Sanders et al., 1996), tabular or lens-shaped, several decimeters thick, and up to tens of meters long (Fig. 2.13). The pegmatites have little mineralogical variation, suggesting that they belong to one single genetic group, and that they have a similar age (pre-Alpine, ca. 208±4 Ma; Sanders et al., 1996).

The Piona Abbey is located on the peninsula, very close to the lake, . It was founded by Cluniac monks in the Middle Ages to defend both the area and the boats on the lake, which at the time, were in danger of being attacked by brigands and pirates. At the beginning of this century, it was restored, and it has been under the ownership of the Cistercian monks of Casamari, who produce a variety of liqueurs there, among which is the famous “Gocce Imperiali”.

Lake Luzern regional geologic setting

The train ride in the morning of day 3 will pass through the Southern and Central Alps, and will bring us to the Reuss Valley, north of the Alps. The Gotthard N-S cross-section (“Leventina” in the south, “Reuss Valley” in the north), will offer, on the entire train trip, views into the structures of the Alpine edifice. The Gotthard area is a climatic boundary, separating two different climate systems north and south of the Alps. It is also the site for the world’s longest railway tunnel to be built (www.neat.ch) with a total length of 57 km, and planned for completion in 2015, with major geological obstacles to be overcome during its construction. The field trip will start on Lake Lucerne, in an area where the Helvetic nappes provide a spectacular framework of Alpine orogeny. These nappes have been overthrusted in the Miocene over the partly deformed molasse foreland deposits and subhelvetic units that flank the lake further to the north, where the excursion will end.

Lake Lucerne is primarily of glacial origin, though



Datum	Ereignis	Sediment-Charakteristik	Bemerkungen
24./25.8.1987	HW: Reuss	Turbidit mit Kristallinklastika (Turbodit T0)	*** Drittgrösster Reuss-HW-Turbidit
25.4.1986	Tschernobyl		Cäsium fall-out
31.7.1977	HW: Schächen	Turbidit mit Karbonatklastika (Turbidit T1)	
1963	Bomben-Peak		Cäsium fall-out
1958	Renovation Axenstrasse: Felssprengung am Ölsberg (Brunnen – Sisikon)	Lokale Schicht mit groben Kalksplittern	Zuweisung nicht gesichert
1951/52	Renovation Axenstrasse zwischen Brunnen und Petersort: mutmassliche Deponien im See	Lokale Kalksandlage	Zuweisung nicht gesichert
3.10.1868	HW: Reuss	Turbidit mit Kristallinklastika	*** Zweitgrösster Reuss-HW-Turbidit
1862–1864	Bau der Axenstrasse	Lokale Lagen mit Kalkbrekzien	
14./15.5.1801	Felssturz Axenberg	Lokale Rutschung mit Grobsandlage; Turbidit aus karbonatischem und kristallinem Silt	
1.9.1774	Erdbeben im Kt. Uri: Rutschungen im Reussdelta	Homogenit; lokal Felstrümmer	
8.12.1769	Felssturz Schwandenflue	Lokale Rutschung; Turbidit aus karbonatischem Silt	
1.11.1755	Erdbeben: Rutschung im Reussdelta	Homogenit	Schwallwellen, viel Schwebstoff in den Flüssen
23.9.1687	Spontane Rutschung im Muotadelta	Homogenit	Schwallwelle; Zerstörungen in Treib und Brunnen
Anfang 17. Jahrhundert	Rutschung im Reussdelta	Homogenit (16.)	Keine genauere Alterszuweisung möglich
18.9.1601	Erdbeben im Kt. Nidwalden: Rutschung im Muotadelta	Homogenit	Sehr grosse Seiches (Zuweisung nicht ganz gesichert)
vermutlich Mitte 14. Jahrhundert	HW: Reuss	Turbidit mit Kristallinklastika (Turbidit TX)	*** Grösster Reuss-HW-Turbidit 1343 (n. Pfister)

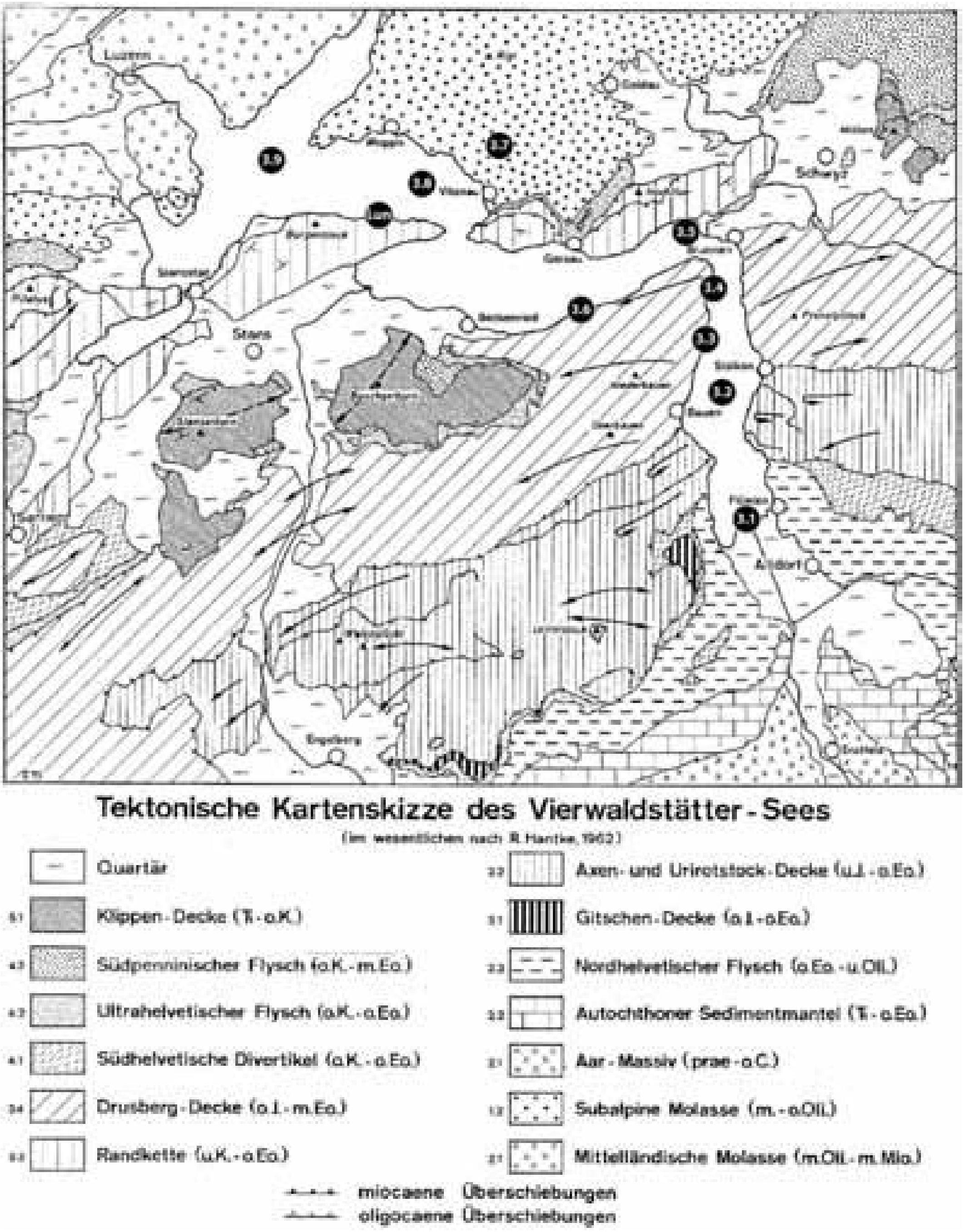


Figure 3.2 - Geological Map of the Lake Lucerne Area. (Hantke, 1961; Trümpy and Trommsdorff, 1980). The major tectonic units are indicated, together with the planned stops/themes on day 3.

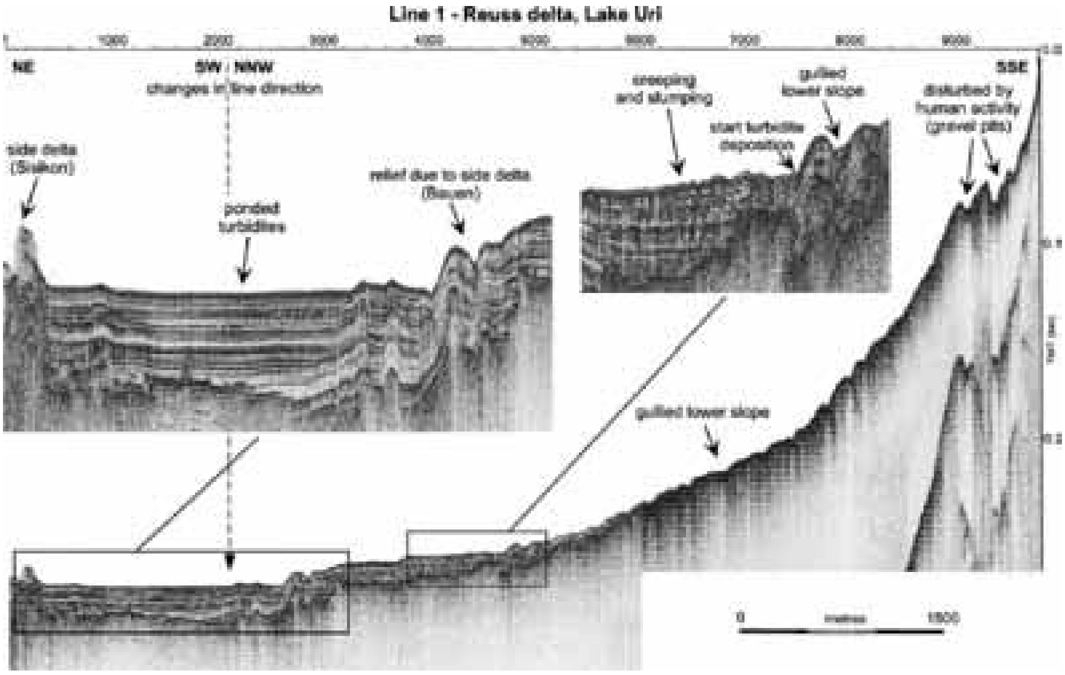


Figure 3.3 - Seismic line of the Reuss Delta (Adams et al, 2001). Note the exponential curvature of the delta slope (except the gravel mining area), reflecting the exponential decay of the transport capacity.

glacial and also fluvial till erosion followed tectonically-inherited structures. Its lake sediments store crucial environmental information from the last Glacial to modern times. The site of numerous natural catastrophes, ranging from earthquakes, to floods and rockfalls, Lake Lucerne and the adjacent valleys are a major traffic route and densely populated. Due to the Alpine character of the catchment and the lake basin, many environmental problems are amplified, so that the lake, with its landscape and human evolution, is a prime example for developing sustainable concepts.

Field itinerary

DAY 3

Train ride from Como across the Alps to Füelen on Lake Uri, the most internal part of Lake Lucerne (Vierwaldstättersee). A ship will take us from there all along Lake Lucerne to the outflow of the lake in Lucerne.

Stop 3.1:

Reussdelta, Flüelen

The delta of the river Reuss is fed by sediment from a large catchment area, covering major parts of the Central Alps (Fig. 3.3). In order to remediate the damage produced by gravel mining activities that have been performed for decades, a new plan will redesign the delta area on ecologically sound and modern landscape principles (www.seeschuettung.ch). New islands will be created by dumping rocks from two large tunnel projects (highway A4 and the NEAT train tunnel) into the delta area, so that the shallow water areas that have been destroyed by the mining activities will be reestablished (Fig. 3.4). The NEPTUN islands will provide a protected natural habitat, while the islands LORELEI will be opened to visitors to be a designated swimming area. The ring-shaped island, created by artist Peter Regli, is of symbolic and mythological significance, and reflects the tunnel-origin of the used rocks. Gravel mining will continue in front of the delta, while respecting the newly-established sustainable concept.

Stop 3.2:

Lake Uri (and Seelisbergsee):

Lake sediments are sensitive recorders of flood events, one of the main natural hazards in Alpine valleys. In 1987, a disastrous flood event occurred, posing questions about the frequencies and intensities of similar events in the past. A study by Siegenthaler and Sturm (1991), identified, in the sediments of the

Figure 3.4 - New islands in front of the Reuss delta, built of rocks from two large tunnel projects. These islands are part of a project that recreates the shallow water areas lost during decades of gravel mining.

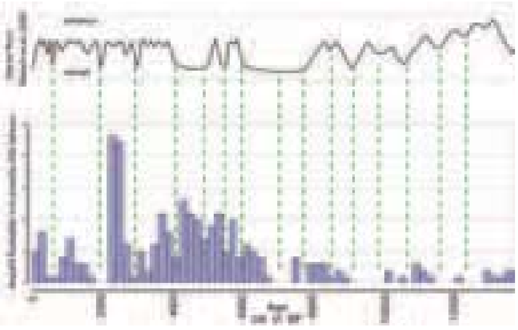


Figure 3.5 - Occurrence of flood events, as recorded by flood turbidites in the Seeli in Seelisberg. Over 250 turbidites are grouped into bins of 200 year duration. This curve is compared to the glacial retreat and advance curve of Maisch et al., 2000.

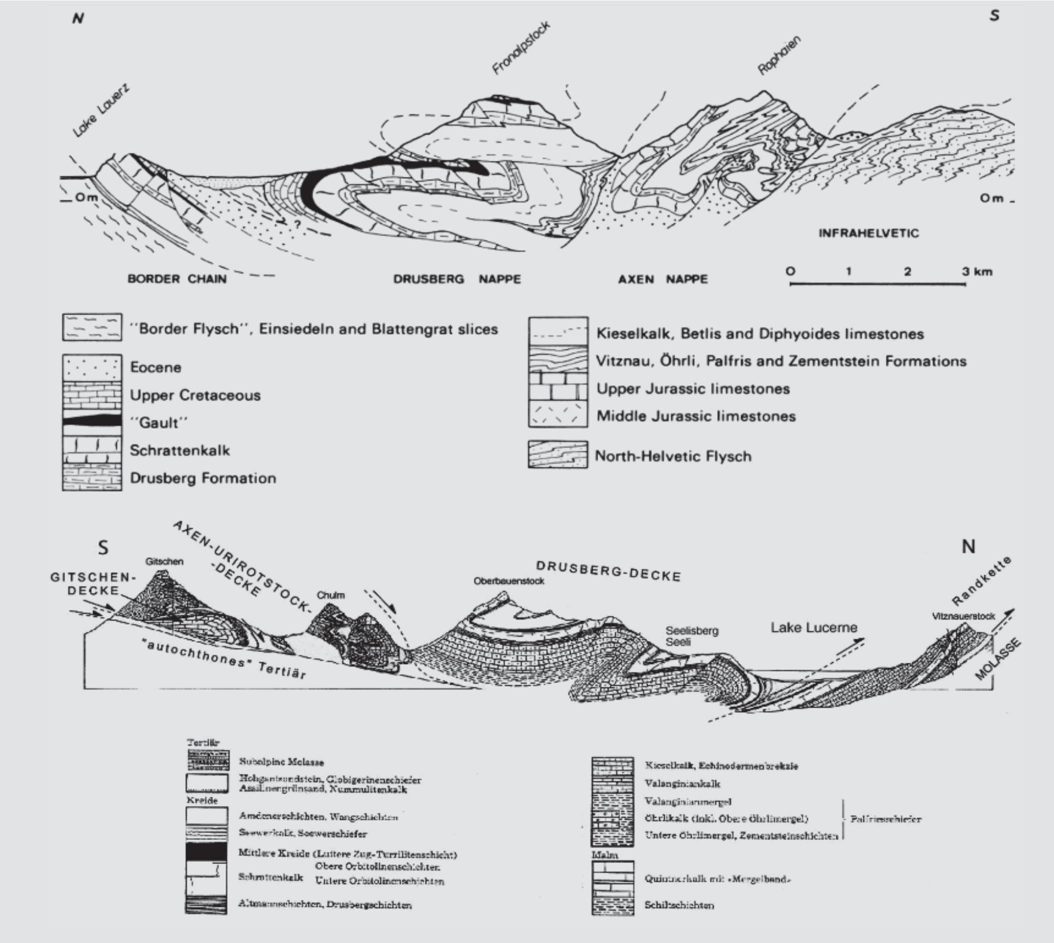


Figure 3.6 - Above: Geological cross-section through Helvetic nappes east of Lake Uri (Hantke, 1961; Trümpy and Trommsdorff, 1980). Below: Geological cross-section through the Helvetic nappes west of Lake Uri (Hantke, 1961).

Figure 3.7 - Painting of Wilhem Tell's jump onto shore, landing safely on Lower Cretaceous Helvetic Kieselkalk (from Tell's chapel, Sisikon).

last 1000 years in Lake Uri, 16 exceptional events (earthquakes, rock falls, slides, floods,...) and on average, 10 basinwide turbidites per century. Two flood events (1868, mid-14th century) had a similar or even stronger magnitude than the 1987 event.

A small karstic lake, the Seeli in Seelisberg, lies 400 m above Lake Lucerne (Fig. 3.1), and contains a complete, ca. 10m-long sedimentary record of the period since the last glacial. The Holocene sediments are characterized by partly varved background sediment, and by intercalated turbidite and slump deposits. Over 300 turbidites have been identified, and most of them can be lithologically related to flood events in the small watershed (Theiler, et al., 2004). A 14-C chronology provides an accurate dating of all these layers, thus yielding the history of strong rainfall events through the entire Holocene. These events can be compared to Holocene climate curves (e.g. glacier advance/retreat curves), and their frequency analysis provide valuable information about the mechanisms of climate change in this central part of the Alps.

Stop 3.3:

The Helvetic nappes on both sides of Lake Uri.

The cliffs on either side of Lake Uri image in a spectacular fashion the structures of the Upper Jurassic to Eocene Helvetic nappes (mainly Drusberg- and Axen-nappes). Their sediments were deposited on the passive southern European continental margin, and consist of limestone shale alternations. The nappes, transported in the Miocene, are characterized by partly steep basal thrusts, and a series of folds and overthrusts (Fig. 3.6). A series of oblique normal stretch faults cut through some of the fold limbs.

Figure 3.8 - Gasthaus Treib, which was flooded by the 1687 tsunami, up to the 2nd floor.

Figure 3.9 - Dinosaur tracks (Iguanodon) in the Lower Cretaceous Schrattenkalk of Risleten Quarry, near Beckenried (www.nmb.bs.ch).

Some of the Cretaceous formations provide excellent and well-visible marker horizons, so that the tectonic structures can be depicted in great detail.

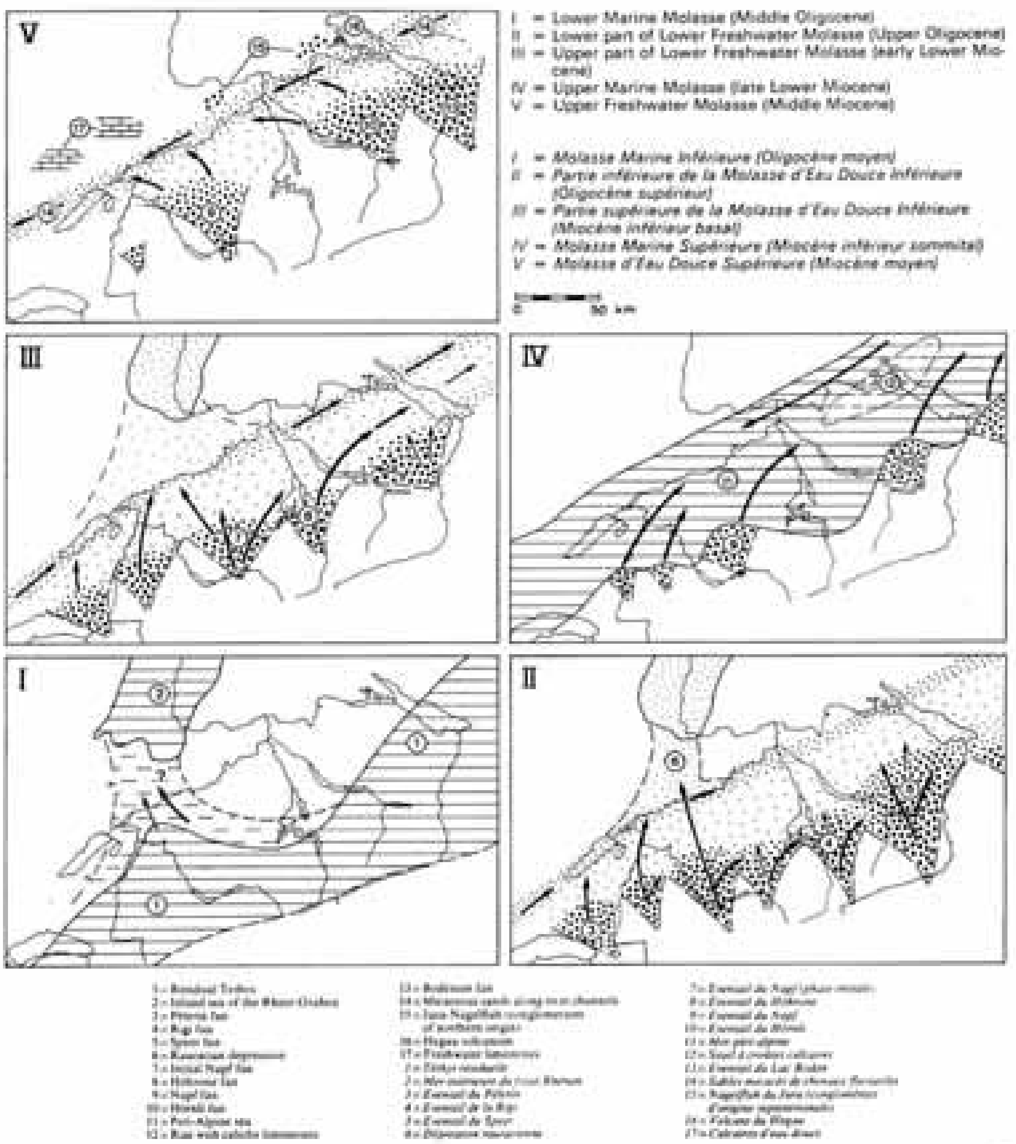


Figure 3.10 - Sedimentation in the Swiss Molasse basins (Trümpy, 1980)

Stop 3.4:

Schillerstein: The history of Wilhelm Tell and other myths

A large natural monument made of well-bedded Helvetic Kieselkalk honors Friedrich Schiller, the writer of the Wilhelm Tell saga (Schiller, 1803). Its golden inscriptions 'Dem Sänger Tells' (to the singer of Tell) were initiated in 1859 by Ambros Eberle, who was a well-known politician, and the owner of one of the most famous late 19th century hotels in the area on the Axenstein This is a mountain name, its correct as is)across the lake, and was well-frequented by all the nobility of Europe. Unlike the similar hotel on the Seelisberg, (this is also a mountain name it has to be "on" not "in") (used today as one of the headquarters of the Maharishi movement of transcendental meditation and hovering directly on top of the birthplace of the Swiss confederation (Rütli)), the

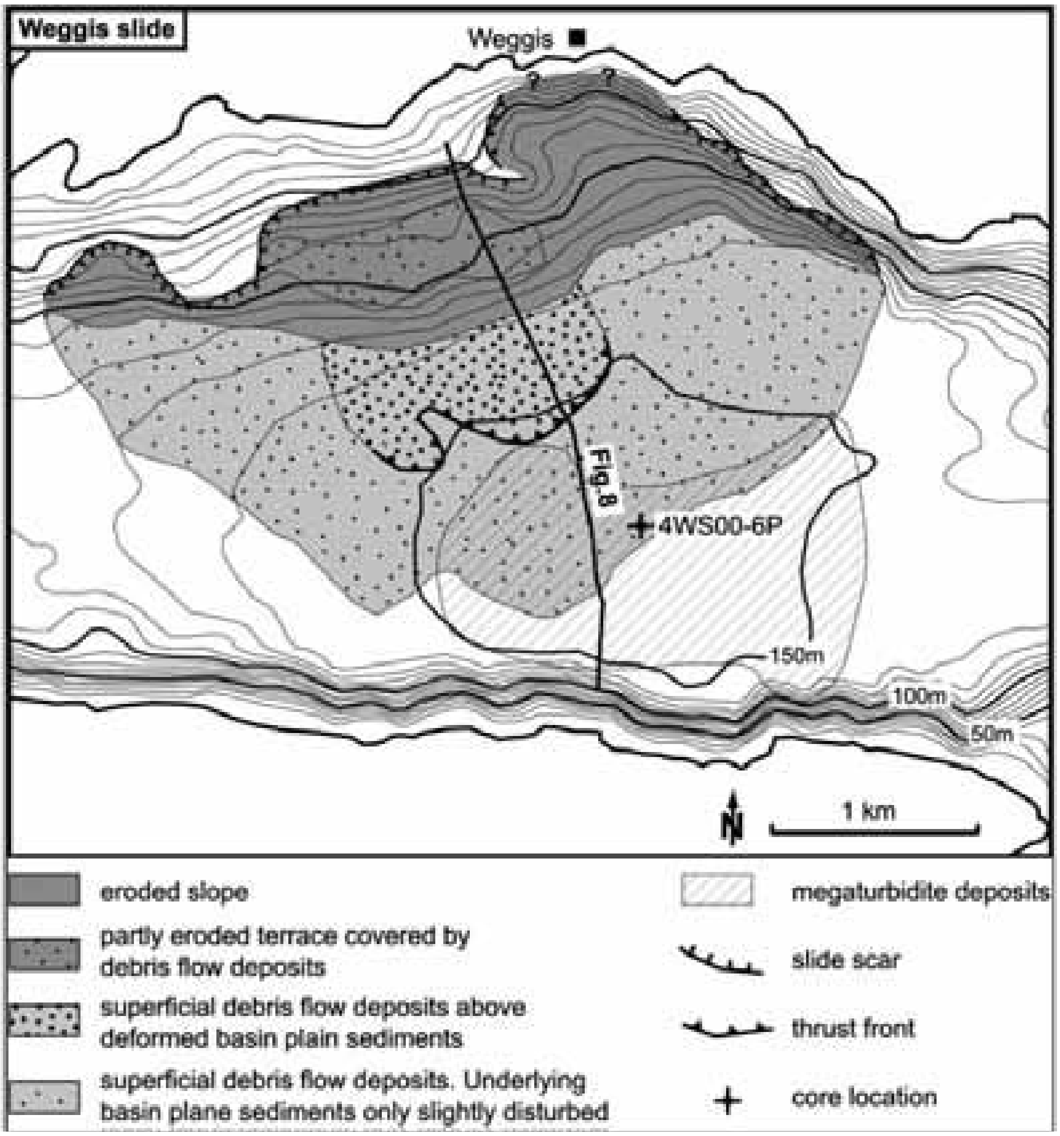


Figure 3.11 - Map of the largest sediment slide of the 1601 earthquake in the Vitznau basin

Hotel Axenstein burned down several times and was eventually torn down. In his play, Schiller places all the locations around Lake Lucerne, such as the 'Tellsprung' at today's Tell's Chapel, where the imprisoned Tell frees himself by leaping ashore during a storm, after he has taken over the rudder to rescue the vessel (Fig. 3.7). The Lake Lucerne area is not only Tell's homeland, also "Mother Helvetia", imaged on all Swiss-Frank coins and the symbol of Swiss freedom, supposedly drowned in the Seeli in Seelisberg, while fighting for Swiss-European integration (Willi and Dubach, 1998).

Stop 3.5:

Muota delta, Brunnen and Gasthaus Treib on opposite shore.

In 1687, during calm and clear weather and despite the absence of a seismic event, a large part of the Muota River delta in Brunnen disappeared in a catastrophic slide. This collapse triggered an over 4 m high wave that ran ashore on the opposite coastline, and damaged the Gasthaus Treib (Fig. 3.8). The water

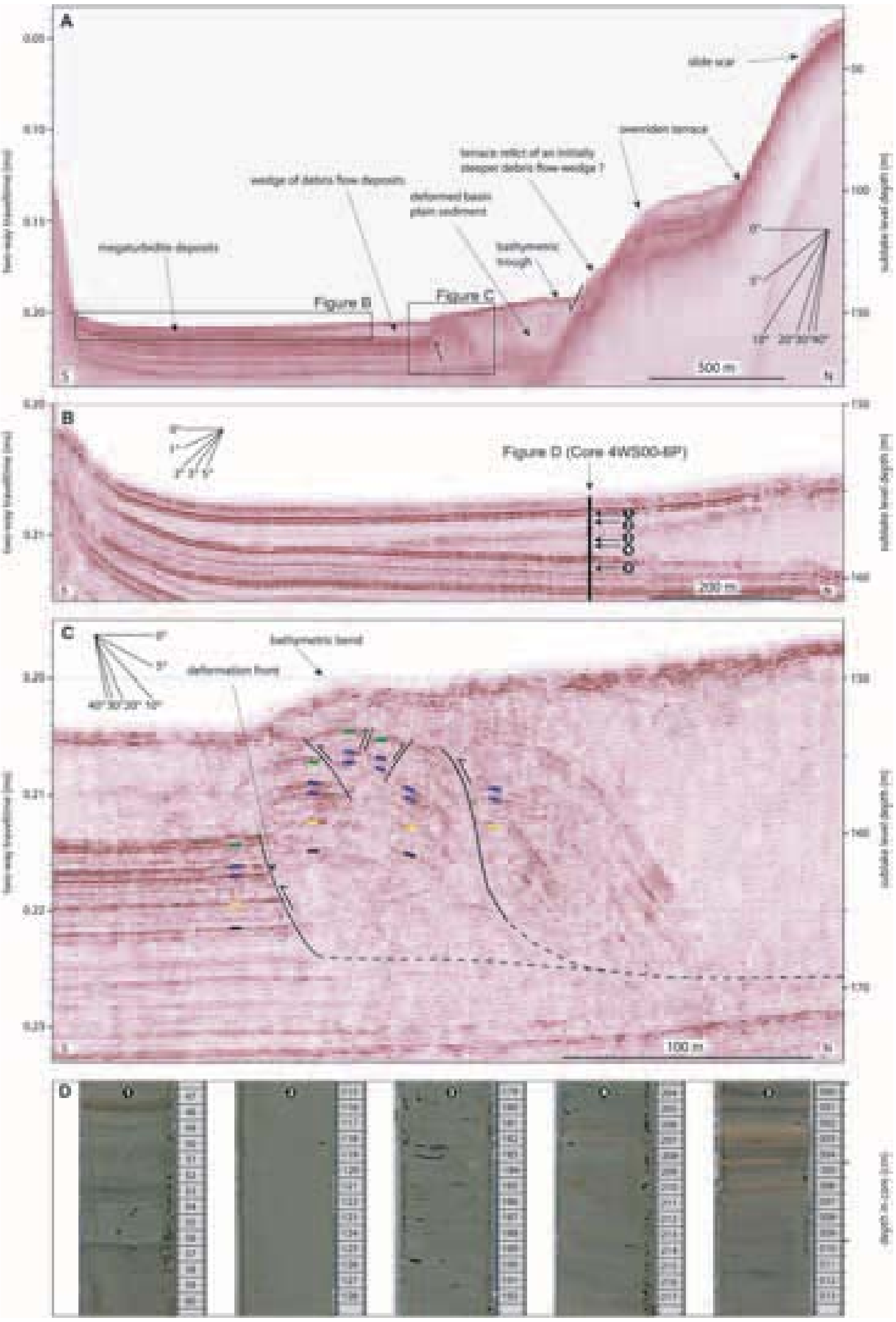


Figure 3.12 - Seismic profiles and core photographs of the 1601 Vitznau slide

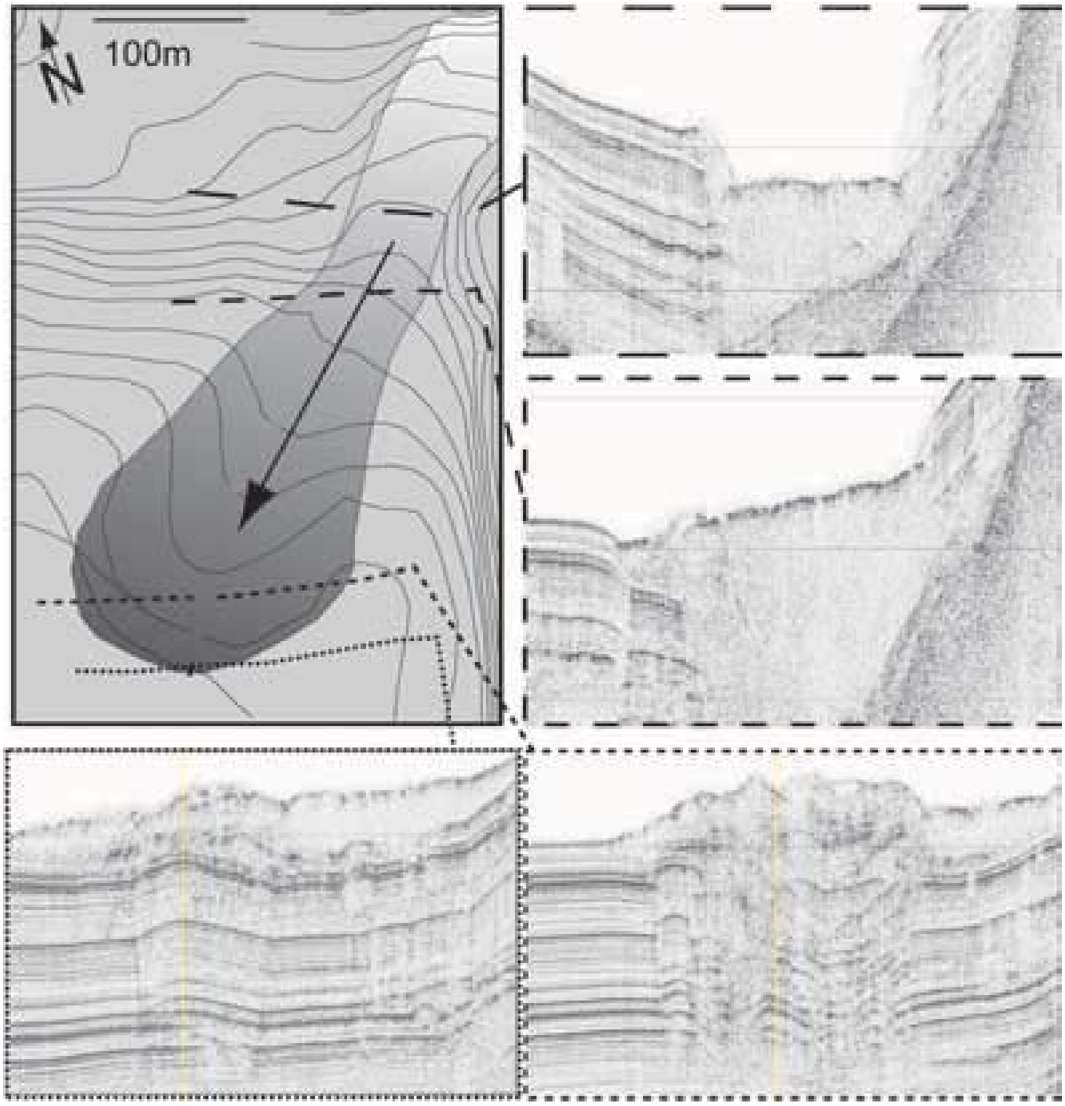


Figure 3.13 - The 1601 Chrüztrichter slide and its internal deformation structures

smashed all windows and window shutters on the second floor and flooded the inside of the house where it turned over a table and knocked down the landlord. Damage was also caused in a nearby village, and in several harbors around the lake. Unlike most of the sediment slides shown in stops 3.8 and 3.9, this slide was not triggered by an earthquake, documenting that individual slumps in delta areas are not reliable indicators of paleoseismic events.

Stop 3.6:

Dinosaur Tracks at Quarry Risleten, Beckenried

A quarry in the Lower Cretaceous shallow-water Schrattenkalk was the first place in Switzerland where Cretaceous dinosaur tracks were found (Fig. 3.9). The tracks were created by dinosaurs of the genus Iguanodon, which reached sizes between 5 and 6 m. Some of the tracks indicate that these dinosaurs partly walked on all four limbs. The tracks are clearly visible from the lake, and were found and investigated by a team from the Museum of Natural History in Basel (www.nmb.bs.ch).

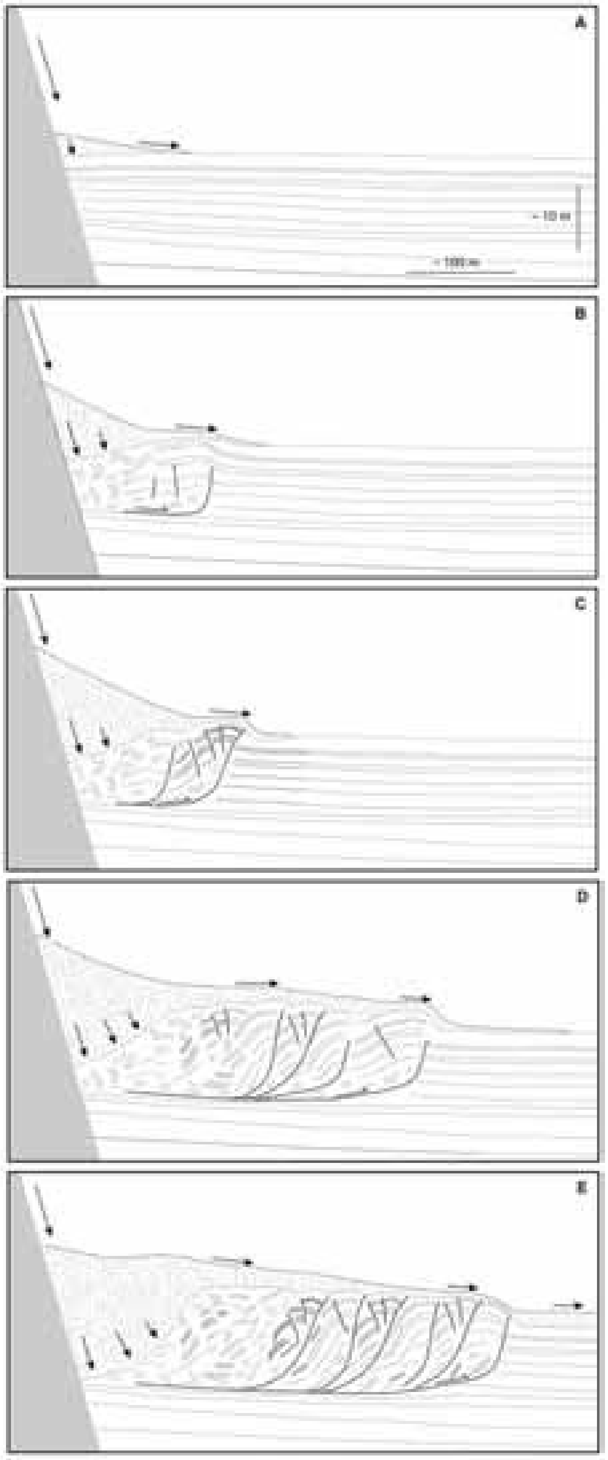


Figure 3.14 - The kinematics of sediment slide formation.

Lunch: Gasthaus Obermatt or Treib

Stop 3.7:

The Rigi Cliffs: conglomerates of the lower freshwater molasse

The Rigi cliffs, clearly visible from the Vitznau basin of Lake Lucerne, are all made up of tilted Subalpine Molasse. The conglomerate-dominated series, the erosional products of the forming Alps, belongs to the Lower Freshwater Molasse, deposited in the Late Oligocene in the large Rigi fan. This fan belonged to a system of at least 7 gravel fans (Fig. 3.10) at the northern margin of the Alps, grading outwards into flood-plains and lakes (Trümpy, 1980). The total thickness might be up to 4 km, consisting mostly of amalgamated, partly channelized, conglomerate beds, with intercalated shales.

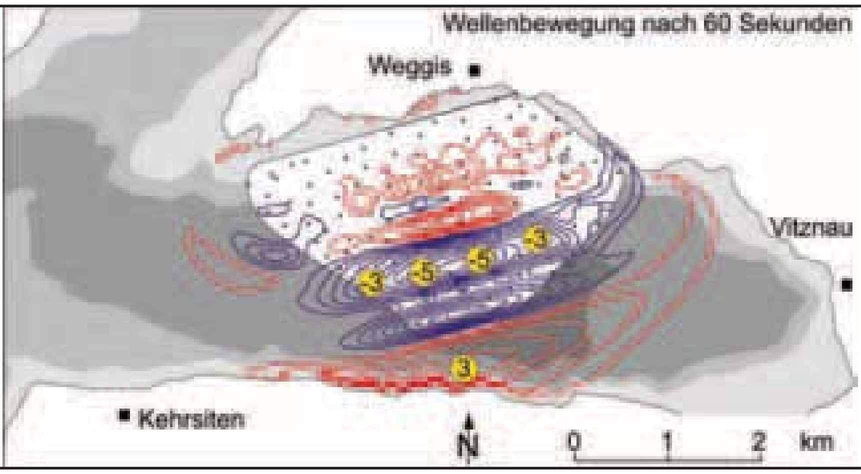
Stop 3.8:

Vitznaubasin: The 1601 earthquake and associated slide deposits

On 18th September 1601, at 2am, an earthquake with an epicenter in the Lake Lucerne area, with an estimated magnitude (M_w) of 6.2, caused considerable damage in large parts of Switzerland and was felt within a radius of 250-300 kilometers, also in the neighboring countries of France, Germany, and Italy. Renward Cysat, the city clerk of Lucerne, noted in an almost scientific report, the events that occurred after the quake. The most frightening features all concerned the lake itself, on which 'mountains of water' built up, and in which fields and houses disappeared from the shore. In addition, the outflow in Lake Lucerne became dry every 10 minutes, so that people could cross the river without getting wet. The reason for these water movements were large subaqueous sediment slides that were triggered by the earthquake (Siegenthaler et al, 1987; Schnellmann et al., 2002). In the Vitznau basin, the largest of these slides covers several km^2 (Fig. 3.11).

This slide was triggered at the northern shore, where a series of slide scars developed (Fig. 3.12). The most characteristic feature of these slides is that the weight of the downwards-moving debris-flow can deform

Figure 3.15 - Numerical modeling of a Vitznau slide induced tsunami wave triggered by the 1601 earthquake. The figure shows the position of the modeled waves at minute intervals, up to 4 minutes after slide initiation. Numbers sample wave height in meters.



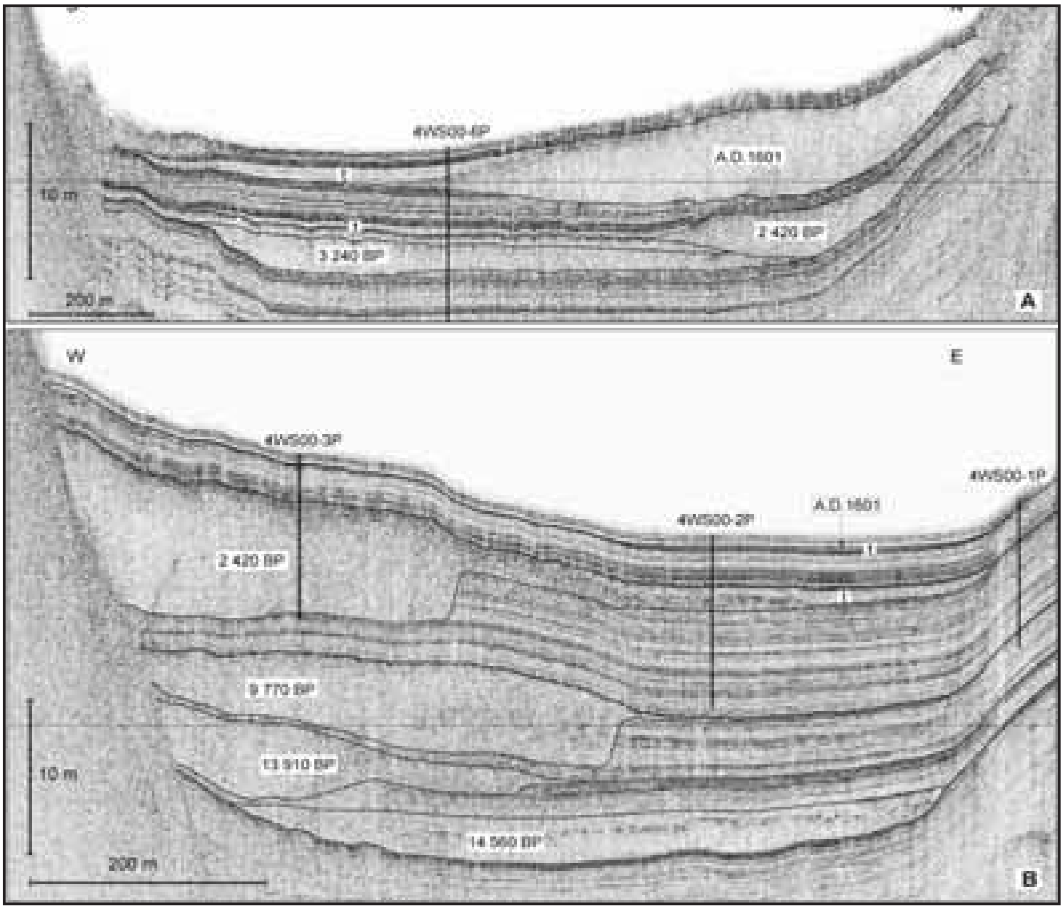


Figure 3.16 - Seismic profiles, showing succession of slump events.

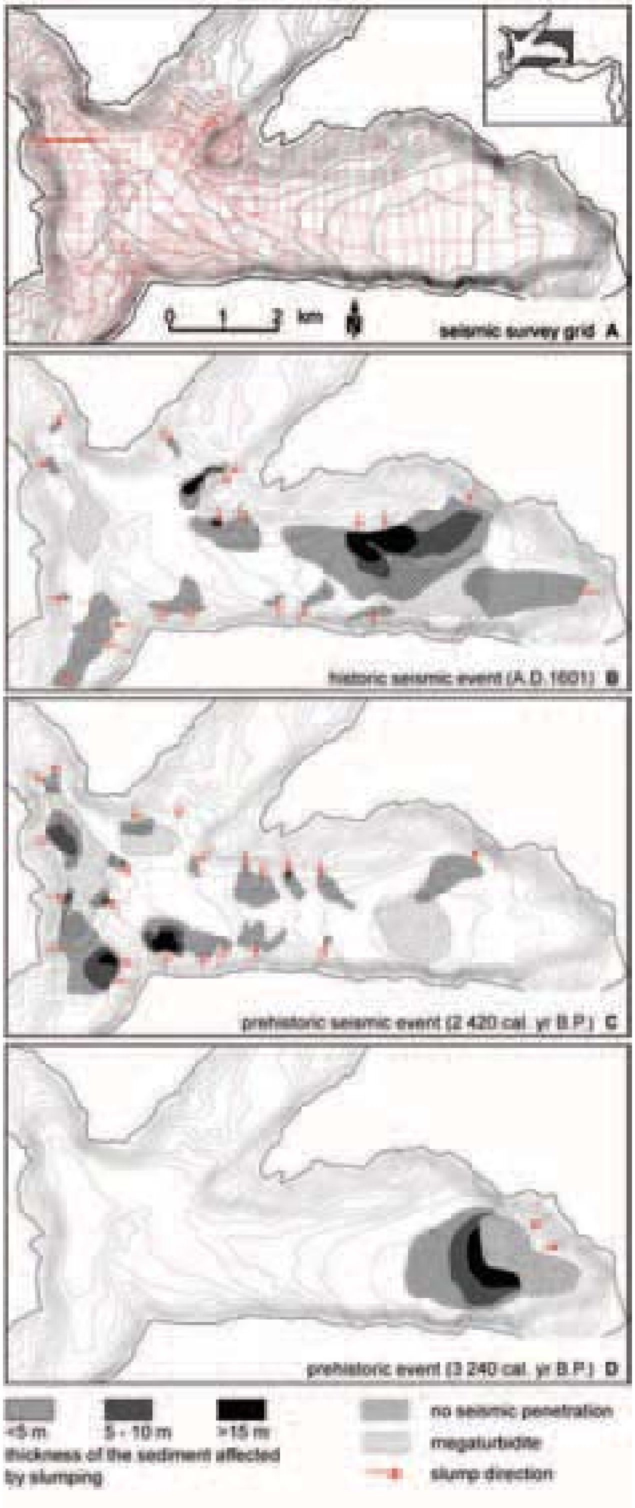


Figure 3.17 - Distribution map of slump events, indicating seismic or aseismic triggering mechanisms (Schnellmann et al., 2002).

the underlying sediments, resulting in small-scale thrust and fold belt structures (Fig. 3.12). This can be seen in the seismic profiles of the Vitznau slide and of the Chrüztrichterslide, that was also triggered by the 1601 earthquake (Fig. 3.13). Both examples document how the lacustrine sediments are overriden and then deformed, as displayed with overthrusts, ramp-folds, and even positive flower structures. The debris-flow deposits usually are overlain in the deepest areas by a thick homogeneous deposit that is formed after the fines settle out of the water column after the event. A kinematic model summarizes a typical sediment slide (Fig. 3.14).

To prove that the sediment slides are indeed responsible for the observed water movements, a numerical modeling of the tsunami waves induced by one of the slides was performed (Schnellmann et al., 2002). The modeling results show that already a single slide can initiate waves larger than 4 meters in height (Fig. 3.15). If, as was the case during an earthquake and is shown in stop 3.9, numerous slides descend at the same time, the individual waves will add up, resulting in even larger water movements.

Stop 3.9:

Chrüztrichter: Holocene earthquake frequency in Central Switzerland

In an intraplate region such as Switzerland, where recurrence periods are usually larger than the time span covered by historical and instrumental records, prehistoric paleoseismic information is needed to gain insight into the frequencies of seismic events. Lake sediments are ideal archives that store traces of prehistoric earthquakes. A seismic stratigraphic study of the lacustrine sediment fill showed that the 1601 earthquake triggered over a dozen slides in the lake (Fig. 3.16). While this event was characterized by synchronous multiple sliding, indicating a common

Figure 3.18 - Martin's panorama of the city of Lucerne, drawn in 1597, just 4 years before the great earthquake hit. The mills in the river stopped working, since the wheels turned dry every 10 minutes due to the seiche movement induced by the sediment slides. People crossed the river, since it flowed every 10 min back into the lake.

trigger mechanism that is seismic shaking, some horizons only displayed one slide, and this is not sufficiently indicative of a paleoseismic event (Fig. 3.17; see also stop 3.5). In addition to the 1601 event, four horizons could be mapped in the subsurface, and all are characterized by multiple slides, and all interpreted to be the result of strong earthquakes (Schnellmann et al., 2002). Like this, five major earthquakes could be identified during the last 15,000 years (Fig. 3.16), providing valuable and new data on paleoseismic activities, that are essential for modern earthquake risk assessment.

End of the field trip: EAWAG lake research center Kastanienbaum or City of Lucerne. The field trip participants will be driven to the train station of Lucerne, which offers frequent international connections.

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field trip itinerary

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FIELD TRIP MAP

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