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PRELIMINARY RESULTS OF TWO ICE CORE DRILLINGS ON MONTE ROSA (COLLE GNIFETTI AND COLLE DEL LYS), ITALIAN ALPS

ABSTRACT: SMIRAGLIA C., MAGGI V., ROSSI GC. & JOHNSTON P., *Preliminary results of two ice core drillings on Monte Rosa (Colle Gnifetti and Colle del Lys), Italian Alps.* (IT ISSN 0391-9838, 2000).

Two boreholes were drilled in the ice on Monte Rosa in 1995 and in 1996, at Colle Gnifetti (4480 m) and Colle del Lys (4240 m), respectively, with the recovery of two cores measuring 24 and 80 m in length. Physical and chemical analyses were performed on the cores, the preliminary results of which are illustrated here. Bore hole temperature and bulk visual stratigraphy and density profiles of the cores were performed directly in the field. At Colle Gnifetti, core bottom temperature proved to be –13.4 °C, whereas density showed values ranging between 0.38 g cm^{-3} and 0.84 g cm^{-3} . The levels of visible Saharan dust from well-known events and peak levels of tritium permitted a determination of the mean annual accumulation at 27.8 cm of water equivalent.

At Colle del Lys the temperature measurements made at the bottom of the drilling hole showed a mean of –11,2 °C, whereas density ranged between 0.32 g cm^{-3} and 0.91 g cm^{-3}, with the close-off at around 40 m depth. A mean annual accumulation of about 170 cm of water equivalent was calculated on the basis of 1963 tritium peak, from thermonuclear bomb tests, and well known 1977 Saharan dust level, as reference horizons.

KEY WORDS: Deep drilling in ice, Glacial chemistry, Accumulation rate, Monte Rosa, Alps.

RIASSUNTO: SMIRAGLIA C., MAGGI V., ROSSI GC. & JOHNSTON P., *Risultati preliminari delle analisi su due «carote» di ghiaccio estratte sul Monte Rosa (Colle Gnifetti e Colle del Lys), Alpi Italiane.* (IT ISSN 0391-9838, 2000).

Due perforazioni sono state compiute sui ghiacciai del Monte Rosa nel 1995 e nel 1996 al Colle Gnifetti (4480 m) e al Colle del Lys (4240 m) con il recupero di due carote di ghiaccio, rispettivamente di 24 e di 80 m di lunghezza. L'articolo presenta i risultati preliminari delle analisi fisiche e chimiche effettuate sulle carote. Misure di temperatura nel foro, osservazioni sulla stratigrafia visibile e profili di densità sono stati compiuti direttamente sul terreno. Al Colle Gnifetti a fondo foro la temperatura è risultata di –13,4 °C, mentre la densità della carota variava fra 0.38 g cm^{-3} and 0.84g cm^{-3}. Indicatori cronologici costituiti da strati visibili di polvere sahariana e picchi di trizio riferibili ad eventi noti hanno permesso di determinare un accumulo medio annuale di 27.8 cm di acqua equivalente. Al Colle de Lys le misure di temperatura hanno evidenziato una temperatura di –11,2 °C a fondo foro, mentre la densità oscillava fra 0.32 g cm^{-3} e 0.91 g cm^{-3}, con il passaggio da nevato a ghiaccio verso 40 m di profondità. La presenza dello strato di polvere sahariana del 1977 ed il picco di trizio del 1963, legato al fallout successiovo ai test termonucleari in atmosfera, hanno permesso di determinare un accumulo medio annuo di 170 cm di acqua equivalente.

TERMINI CHIAVE: Perforazioni in Ghiaccio, Glaciochimica, Accumulo netto annuo, Monte Rosa.

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INTRODUCTION

Recent developments in our knowledge of global environmental and climatic variations and their relationships with the composition of the atmosphere, are largely based on analyses of ice cores extracted by means of deep drilling on the polar ice sheets. From the Vostok drill hole in the Antarctic at the start of the 1970s (Jouzel & *alii*, 1987) to the more recent ones at Summit in Greenland in the early 1990s (Johnsen & *alii*, 1992; Dansgaard & *alii*, 1993; GRIP Members, 1993; Alley & *alii*, 1993; Grootes & *alii*, 1993), great efforts have been concentrated on the analysis of these cores, which reflect geographical situations where the snow accumulation is preserved almost in its entirety, where local sources of pollution are very low and where one can go back in time for over 400000 years (Delmas, 1992; Jouzel & *alii*, 1993; Petit & *alii*, 1999).

Yet, even at middle latitudes it is possible to obtain useful and supplementary data with respect to the polar glaciers. Some of these areas are located in regions with more anthropic development. Thus it is possible to collect information not only of a climatic nature, but especially information of the anthropogenic type (Wagenbach, 1989).

In this context, the Alps situated in Western Europe, in a region densely populated since early times, and highly industrialized, represent a good position for understand the direct impact of the man-made compounds on the troposphere. Even if the snow accumulation on Alpine glaciers is often affected by the local meteorological conditions, and the available chronological records are very short (ranging from several decades to several centuries), affected by lack of accumulation mainly due to the wind erosion, the firn and ice cores extracted there constitute irreplaceable natural archives of the history of the anthropogenic impact on the atmosphere and European environment (Oeschger & *alii*, 1977; Maupetit & *alii*, 1995).

In any case, sites where ice drilling can be conducted for climatic and antropogenic impact studies, are very rare in the Alps. In fact, these operations call for very high altitudes (over 4000 m) where the maximum temperatures rarely exceeds 0 °C, and thus the effects of percolation due to melting are reduced («cold» glaciers) (Haeberli & Alean, 1985). Other important character is the morphology of the glacier, that must be suitable (saddles or ice-caps) in order to reduce deformations in the ice stratigraphy due to ice flow.

Up until 1996, there were virtually only two sites. The first is Colle Gnifetti (4454 m) between Punta Zumstein (4563 m) and Punta Gnifetti (4554 m) in the Monte Rosa massif, lying almost exactly on the Italian-Swiss border. This is now a classic location where Swiss and German researchers began drillings twenty years ago (Oeschger & *alii*, 1977). The second site is Col du Dôme (4250 m) in the Monte Bianco massif in France, and where, following up on the surveys conducted by Lliboutry in the mid 1970s (Lliboutry & *alii*, 1976), drillings were resumed again at the beginning of the 1990s (Maupetit & *alii,* 1995; Van der Velde & *alii*, 1999, 2000).

In the summer of 1996, following a test drilling hole on Colle Gnifetti made in 1995, an Italian team conducted another drilling operation on Colle del Lys at about 4200 m, remaining within the Monte Rosa Group.

This report is aimed at illustrating field activities and the preliminary results of the analyses of the ice cores obtained from these two drilling operations.

SITE SELECTION AND DRILLING

The first drilling (CG1/95) was carried out at the beginning of the summer of 1995 at an altitude of about 4480 m a.s.l. slightly above the most depressed area of Colle Gnifetti. The basic objectives were to gain experience in drilling on Alpine ice and obtain an ice and firn core, the analysis of which would permit comparisons with data obtained in adjacent areas. The CG1/95 was drilling around 200 m upstream, towards the Punta Gnifetti, respect the Swiss-German drilling sites.

The second drilling operation (CDL1/96) was carried out in the first week of June 1996. The site selected is situated on Italian territory in the drainage basin of the Lys Glacier, at 4240 m a.s.l. This is an area that should supply information characterized by high temporal resolution regarding the physical and chemical characteristics of the air masses coming from the south and their evolution over time. In addition, it should be emphasized that the Lys Glacier is a structure for which data on thickness obtained by radar and data on the meteorological situation (ENEL-CRIS meteorological stations at Colle Vincent, 4088 m and at Colle del Lys, 4240 m) were already available (fig. 1).

The drilling was carried out using an electromechanical wire drill system that can reach a maximum depth of 150 m. Already used within the Programma Nazionale Ricerche in Antartide (PNRA-Italian National Research Antarctic Programme), this drill makes it possible to obtain cores measuring 50-90 cm in length and 10 cm in diameter. Moreover, this tool also allows for recovery of the drilling cuttings, collecting them in a container found on top of the corer, keeping the drill hole clean and providing additional material for possible analysis. Because technical problem, after 3 days the operations at Colle Gnifetti reached only 24 m of depth. Some problems arose also to remove the surface cores (the first 5-7 m), because the very limited density of the firn made it difficult to detach them from the bottom of the drilling hole. In any case, removal results were excellent, reaching over 90% of the entire core.

At Colle del Lys, in five days of work, a depth of 80 m was reached with removal of over 90% (for the first 60 m, removal virtually reached 100%). Core quality worsened steadily in the lower part (the last 20 m), probably due to the range of stress that the basal ice undergoes. Small rock clasts with a diameter range of several mm were observed in the cores of the bottom part (77-80 m in depth). These clasts indicate the proximity of the base of the glacier. Drilling was thus stopped at that point as the type of tool being used would not have been capable of drilling the basal ice.

OBJECTIVES AND METHODS

There were two basic objectives for this research: 1) to study the history of the climate and the atmosphere in the last half of XX century; 2) to evaluate the impact of anthropogenic factors in the Central Alps in Italy.

The analyses were planned in the following order:

– electric conductivity in solids (ECM), which measures in qualitative terms the chemical content of the ice, which is generally considered to be proportional to the acid contents (Hammer, 1987) Given its high resolution

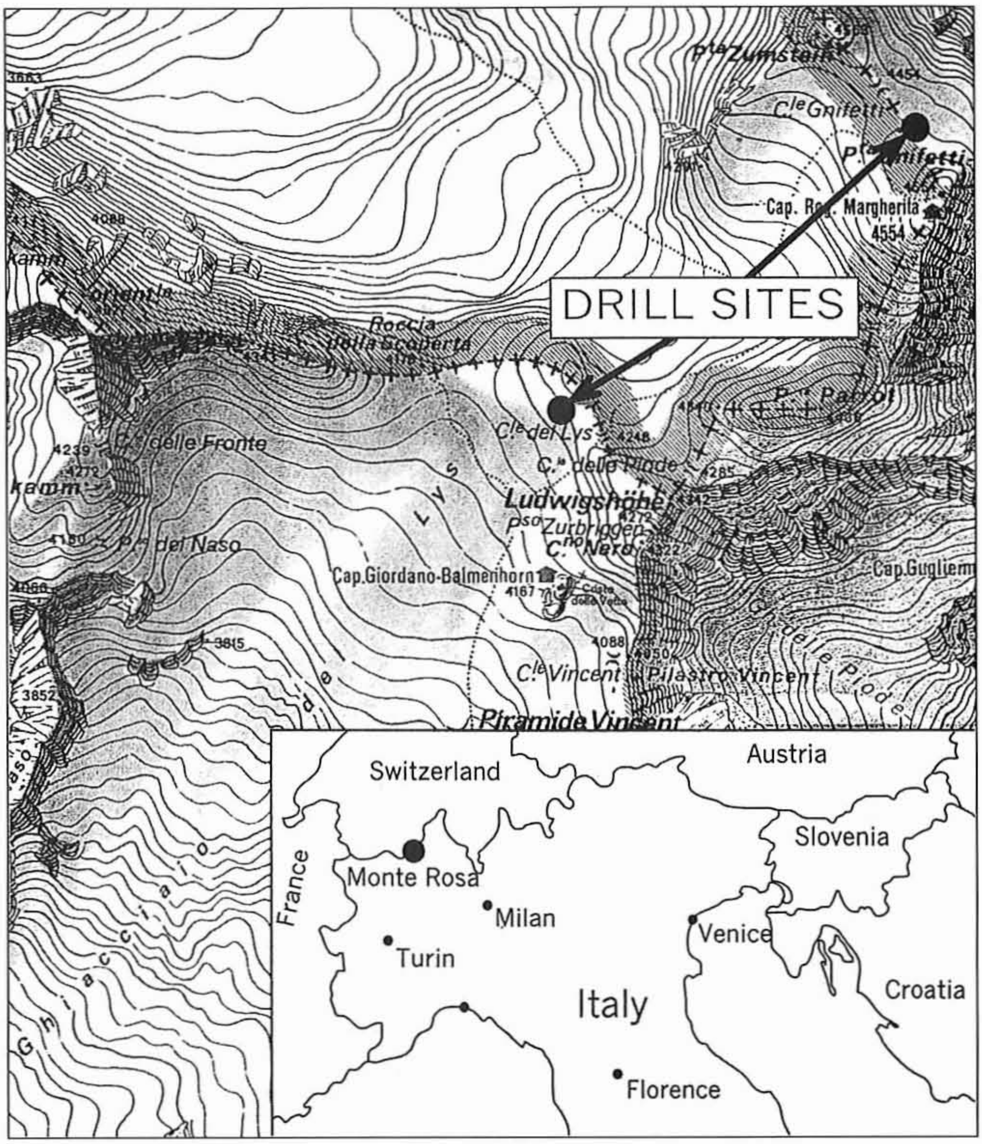


FIG. 1 - Drilling site localization on the Monte Rosa Group. The Colle Gnifetti is a saddle positioned at the upper part of the Grenz Glacier; the Colle del Lys is a saddle between the Grenz Glacier, flowing north, and the Lys Glacier, flowing southwest.

(1-3 mm), this type of analysis can also reveal events of brief duration, but characterised by strong intensity (peak levels of anthropic or volcanic acidity).

– chemical analyses of the major ions, particularly sulphates and nitrates, which are important in determining the anthropic influence on this Alpine sector. The analyses of the chlorides and ammonia supply information on the influence of farming activities carried out in the Po Valley area (Northern Italy), as well as on currents of marine origin (Mediterranean) that reach the Alpine zone. Sulphate and ammonia records provide also a good seasonal signal used for define annual variation of accumulation and provide a useful timescale of the ice core. In addition, the analysis of components of crustal origin such as Ca^{++} e K^{+}, can supply additional indications regarding both the dust record and the soluble-insoluble fractionation of particular elements found in the atmospheric aerosol. Trace metals, are relevant for the anthropic impact, as the lead is strictly related to the vehicles fuel, that could register the decrease due to the use of benzenic compound instead of lead, from the mid of '80s.

– analysis of the stable isotopes ($\delta^{18}O$ and δD), important for the strictly relationship with the temperature and the sources of the air mass where the precipitation was originate. Also the stable isotopes, as some chemical species, can provide record of seasonal fluctuations of which make it possible to create a chronological scale and to estimate the accumulation rates, which are essential data for dating and the study of the mass balances of glaciers.

– analysis of the radioisotopes, particularly tritium, the concentration of which can contribute to dating the cores (in fact, the maximum concentration in the atmosphere dates back to 1963 on the occasion of the last nuclear experiments in the atmosphere) and the alpha and beta activity, used to identify the Chernobyl event (may 1986), other important regional marker. These measures were important as well known reference horizons used for dating the ice core and for define a reliable time-scale to apply at all the records and for comparison between different ice cores.

– analysis of insoluble dust, with a special focus on materials originating from local (bedrock outcrop surrounding the drilling site), nearby (industrial and farming activity in the Po Valley) and remote sources (North Africa).

– analysis of the physical properties of the ice, particularly the density profile and crystallography.

THE PRELIMINARY RESULTS

COLLE GNIFETTI

During the drilling operations, a series of measurements were carried out directly in the field. In the Colle Gnifetti drill hole, the temperature was measured using a PT100-type thermometric probe. These measurements yielded temperatures well under 0 °C even just a few meters below the surface. The temperature at the bottom of the hole (24 m) was –13.4 °C (after 24 hours of stabilization). Therefore, the fact that the work was being done on «cold» ice was confirmed, as was the fact that percolation of meltwater should be very limited. In any case, it was observed that although refrozen ice lenses were numerous along the length of the core, vertical veins were lacking completely. Therefore, percolation of meltwater for a few centimeters before refreezing, typical of infiltration-recrystallization zone (Shumskii, 1964) cannot be excluded.

The density profile of CG1/95 (fig. 2), taken during the drilling operations, shows readings within a range of 0.38 g cm^{-3} and 0.84 g cm^{-3}, with a mean of 0.67 g cm^{-3}. A distinct uniformity is observable in the density pattern with a gradient in the first 5 meters of water equivalent (hereafter: m w.e.) of about 0.024 g cm^{-3} m^{-1}. At depths greater than this toward the bottom, the gradient decrease, and reaching 0.016 g cm^{-3} m^{-1}, with strong fluctuations in density particularly between 7 and 11 m w.e. in depth, mainly due to the high variability in the firn facies. The bottom of the drilling hole revealed a density nearing the close-off (Paterson, 1994). A comparison of these core data with those obtained by the Swiss teams in 1976 and 1977 reveals that in the latter, the firn-ice transition takes place at greater depths. More specifically, in the case of the core extracted in 1976, a density of 0.81 g cm^{-3} was reached at a depth of 31 m, whereas the core extracted in 1977 yielded a density

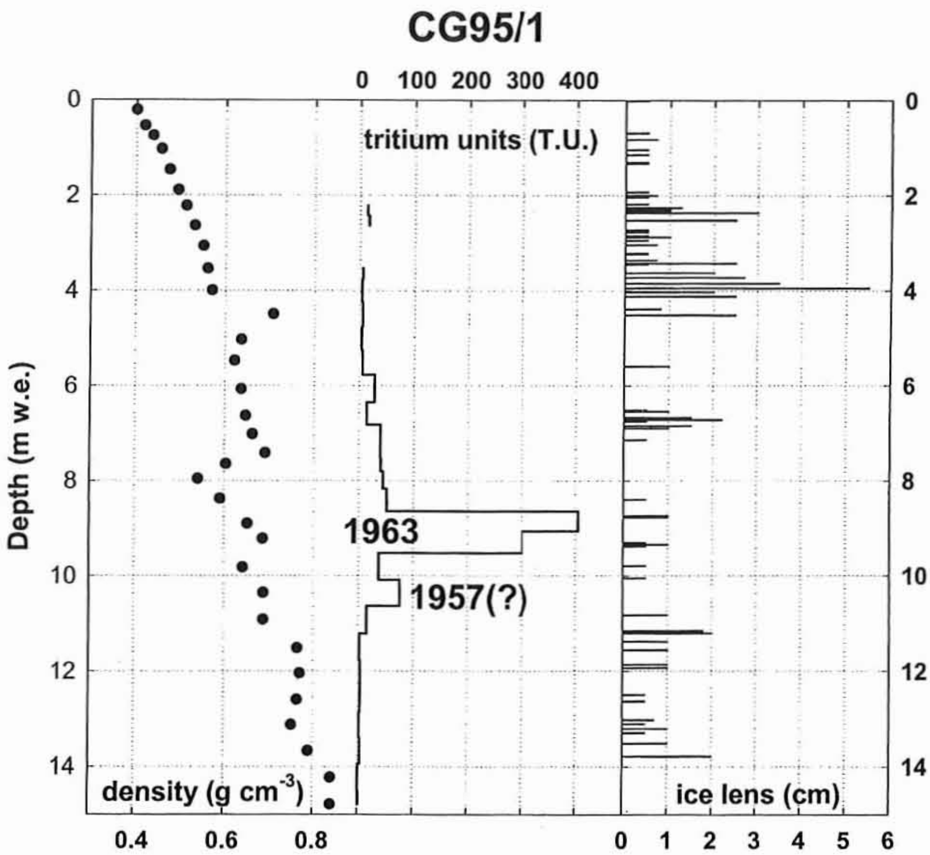


FIG. 2 - The Colle Gnifetti CG1/95 records: density profiles, tritium concentration and ice layers. The tritium profile shows the two reference horizons of thermonuclear bomb test in '57 and '63. The ice layer record show a maximum concentration on the top of the core.

of 0.84 g cm^{-3} at a depth of 35 m. At depths equal to that reached by the drilling operations conducted in 1995 by the Italian team, the resulting density was 0.75 g cm^{-3} (Gäggeler & *alii*, 1983). Normally, the large variability of snow deposition and wind effect on the accumulation, typical of the Alpine glaciers, is not sufficient to explain these differences in the close-off depth. Another reason could be related to the glacier flow and the movement of the ice upstream the bore hole.

The analysis of the stratigraphy revealed the presence of numerous ice layers and ice lens and some visible dust levels (fig. 2). The ice layers are concentrated particularly in the upper part of the core (between 1 and 5 m w.e.) with maximum thickness that reach 5 cm (concentrated at the depth of about 4 m w.e.). Other concentrations of ice layers are found at a depth of about 7 m w.e. and at greater depths, between 11 and 14 m w.e. These concentrations may be linked to periods of intensive radiation, particularly during the summers. The visible dust layers, not showed in fig. 2, are characterized by yellowish coloured firn strata, with thickness ranging between 2 and 20 cm. They are related with events involving dust of North Africa origin, mainly Sahara, that seasonally reach the Alps, and they can become markers of great importance if the event is high concentrated, in that their deposition is synchronous throughout the entire Alpine area.

The tritium (^3H) levels (fig. 2) showed a major peak at a depth of 8.7 m w.e. with levels reaching 400 tritium units (1T.U. = 1 atom of tritium each 10^{18} atoms of H), and a secondary peak at 11 m w.e. (70 T.U.). The main event is linked to the thermonuclear tests conducted in 1963, the last year before the ban of nuclear testing in the atmosphere. The secondary event may be correlated with the previous period of atmospheric nuclear tests conducted in 1957. The results from greater depths reached minimum levels and are linked to natural events (between 1 and 2 T.U.). Following the peak level of 1963, the tritium pattern in the upper part of the CG1/95 core shows a sharp drop that is almost asymptotic, related to the drop in radioactive fallout owing to depletion of the reserves in the atmosphere and to the radioactive decay that is typical of this isotope (H^3 half-life period: 12.5 years). It is clear that these events, which are well-known and of global impact, are excellent reference horizons for dating cores and for estimating net annual accumulation.

Core dating and the evaluation of the net annual accumulation were carried out in two separate phases. First of all, using the density profile, the depths were re-computed in terms of water equivalent (m w.e.) Then the depth-time curve was plotted starting from the known points represented by the two tritium peak levels (1963 and 1957) and from the Saharan dust event that is found at a depth of 5.5 m. This layer is correlated with a very important event that occurred in the spring of 1977 and that is evident throughout the Europe and reach the Scandinavia (Wagenbach, 1989). Evidently another check point consists in the glacier surfaces and it is referable to the spring of 1995. The net annual accumulation resulting from these figures is equal to 27.8 cm w.e. per year, at least for the period starting from 1963 to the present. If this accumulation is extrapolated as far as the base of the core, it can be estimated that at a depth of 25 m, the ice originates from snowfall of 1942-43, and the entire core covers about 52 years of the atmospheric history of the Monte Rosa area.

The chemical analyses on the ionic part and the trace metals are currently in progress. These analyses will indicate variations in both natural and anthropogenic emissions. The analyses of the stable oxygen and hydrogen isotopes will reveal the source areas of the air cells from which the snowfall originates and the temperatures at which it occurs. The study of the Saharan dust levels will furnish information on the quantity and mineral typology characterising the dust itself.

Colle del Lys

An outline of the preliminary results of the drilling performed at Colle del Lys is provided in Maggi & *alii* (1997) and in Rossi & *alii* (1998).

Temperature measurements

As relates the temperatures the data available regard the measurements made inside the drilling hole (CDL1/96) after drilling was completed. A set of three PT100 probes was placed in the bore-hole and they were connected to a data-acquisition logger. The probes were positioned at 15 m, 50 m and 80 m in depth. At the depth of 15 m, the temperature was –6.0 °C, and it dropped to –10.8 °C at 50 m. The temperature at the bottom of the drill hole reached –11.2 °C. The gradient proved to be 0.13 °C m^{-1} between 15 and 50 m in depth and it was slightly lower for the sector between 50 and 80 m (0.01 °C m^{-1}). Thermometers were not positioned at depths in the middle range and this did not permit a precise evaluation of temperature patterns in relation to changes in depth. In any case, it is clear that the gradient is negative moving downward, and this differs from the results observed on Colle Gnifetti nearby (Haeberli & *alii*, 1988), where an increase in temperature was observed down to bedrock. Some difficult arise for explain the difference of between Colle Gnifetti and Colle del Lys temperature profiles, and modelling of the heat balance of the Lys Glacier will be done for interpret this discrepancy.

Although the temperatures observed in the CDL1/96 hole are higher than those resulting for Colle Gnifetti, the Lys Glacier is definitely cold, at least in the uppermost sector of the glacier. From the correlation of the drill hole temperature at –15 m with the site altitude in the graph proposed by Haeberli & Alean (1985) (fig. 3), it can be observed that Colle del Lys (CDL) is situated in the field of the cold glaciers, in good correlation with all other cold Alpine glaciers. This represents a further confirmation that the site selected presents thermal characteristics in line with the expected characteristics. In this case as well, the presence of numerous refrozen ice lenses represents confirmation that this is an infiltration-recrystallization zone.

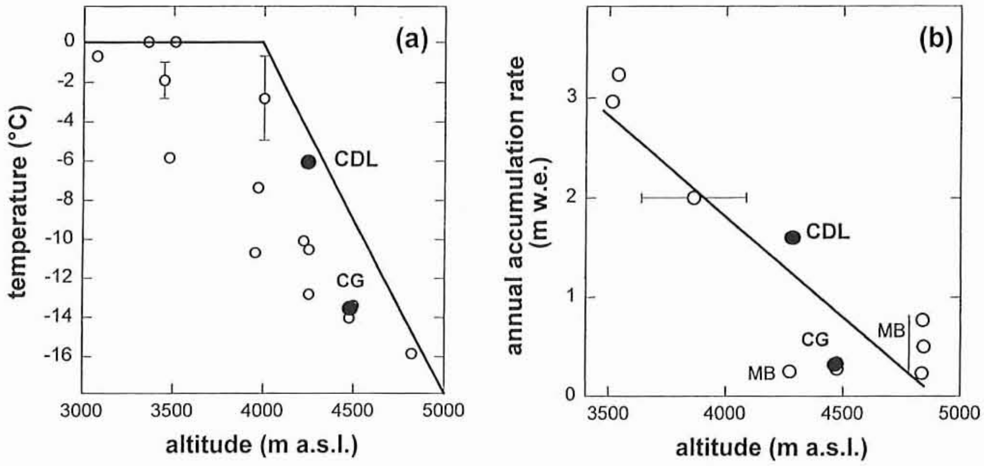


FIG. 3 - Ice and firn temperatures (a) and accumulation rate (b) at high altitudes in the Alps (from Haeberli & Alean, 1985, modified). The Colle Gnifetti (CG) and Colle del Lys (CDL) –10 m depth temperatures are indicated in relationship with site altitude and mean annual accumulation rate. Both the site can be considered to have «cold glacier» conditions.

Density measurements

In the case of the CDL1/96, the density of each piece was measured in a cold-room laboratory at the temperature of –18 °C (fig. 4). Densities varied from a minimum of 0.32 g cm^{-3} at the surface to a maximum of 0.91 g cm^{-3} in the deepest parts. The firn-ice transition was found at about 40 m depth, with close-off density of 0.85 g cm^{-3}. A high scattering of density data was found in the first 20 m of the core, where the high concentration of ice lenses characterises the ice core.

Density gradient variations may instead be related to the various phases of the process of transformation of the snow into ice. Down to about 7 m w.e. with a gradient of 0.028 g cm^{-3} m^{-1}, the first densification processes starts through the compaction and denser packing of the crystals leading to a density of about 0.55 g cm^{-3}. Within the range of 7 to 25 m w.e. approximately, the increase in density followed a gradient of 0.013 g cm^{-3} m^{-1}, around half of the first 7 meters, which leads to complete firnification and to the firn-to-ice transition with a density of 0.85 g cm^{-3} when the «sealing off» process has been completed. Between 25 and 50 m w.e., there was only a slight increase in density (the gradient was lower than 0.003 g cm^{-3} m^{-1}) and it even exceeded 0.91 g cm^{-3}; this is the phase in which the air bubbles enclosed in the individual ice crystals undergo compression (at depths exceeding 50 m, the poor quality of the core, broken up into small fragments, did not permit further measurements of the density) (Paterson, 1994).

Visible stratigraphy

The visible stratigraphy is indicated in figure 4 and it was logged directly in the cold-room laboratory. The presence of re-frozen ice lenses and layers is evident. The distribution of the ice lenses could also offer some indications of a chronological nature. In fact, the greatest concentrations of ice lenses and layers should correspond to summer with high temperature and intensive solar radiation.

It was also possible to observe six yellowish coloured layers of dust in the core. These layers can be attributed to important events of dust from the North Africa due mainly to the atmospheric turbulence during the spring-summer period. The most distinct layer has a thickness of 15 cm and is found at a depth of about 25 m w.e. This layer could be attributed to the particularly intensive event of 1977. Should this be confirmed, it would constitute a major chronological horizon, which would permit an estimate of the net accumulation between 1977 and 1996 amounting to 130 cm (+/– 10 cm) of water equivalent annually.

Radioactive isotope analysis

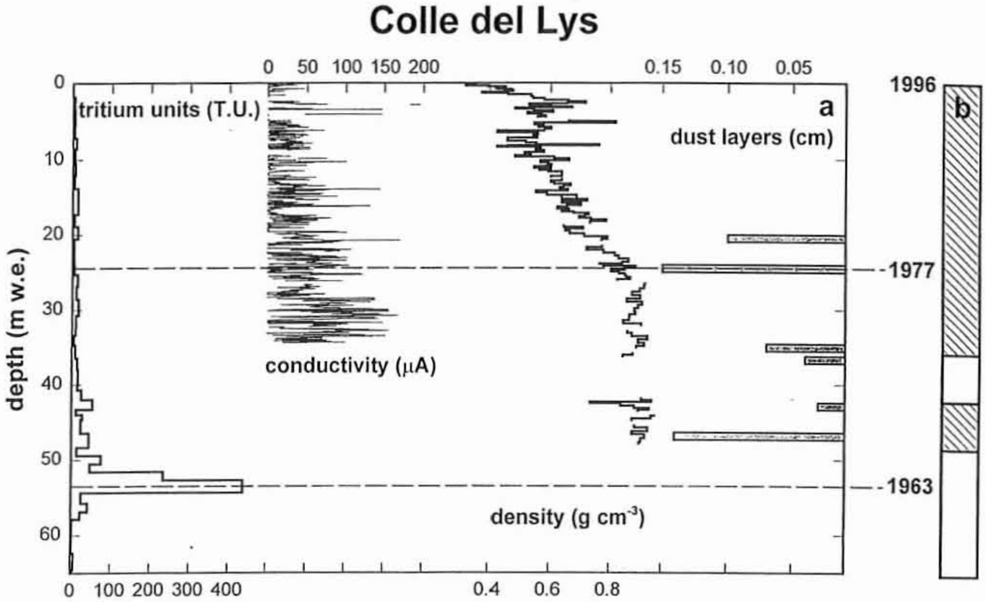
Preliminary data regarding the tritium concentration are available at this stage of the analyses. The concentration of ^3H in the atmosphere and thus in precipitation, has increased following the production of this isotope caused by the testing of thermonuclear bombs in the atmosphere and which saw an escalation in 1953-54, in 1958-59 and in 1962-63. The results of these analyses are presented in figure 4.

Variations in the concentration of ^3H, which permit identification of individual annual strata, were not observable at any point in the core. However, a peak level of about 400 T.U. clearly stands out at depth of 53 m w.e., and this could be attributable to the 1963 episode. In this case, there would have been an annual accumulation of 170 cm (+/– 10 cm) in water equivalent between 1963 and 1996. As one may note, this value is quite more higher to the value postulated taking into account the presence of the layers of Saharan dust. The comparison of these records with the planed chemical and stable isotope measurements could be helpful to understand this variability on the accumulation rate.

Conductivity

The electrical conductivity in solids (ECM) of ice were performed in a cold-room laboratory, using an instrument

FIG. 4 - The Colle del Lys ice core (CDL1/96): a) Tritium profile, with the 1963 thermonuclear bomb test peak; the electrical conductivity in solid, with the acidity decrease trend following the amelioration of the atmospheric pollution trend; the density profile, that show the close-off around 25 m w.e. depth (around 40 m of real depth); the major dust layers record, with the 1977 Saharan dust, very useful for dating purpose. The dashed line show the two reference horizons used for define the mean annual accumulation rate and for the preliminary timescale of the ice core. b) The log of ice core quality; the dashed areas show good quality of the core, the white area show the low quality of ice core.



from the University of Heidelberg (Maggi & *alii*, 1997). The system consists in having two electrical conductors moving on the pre-cleaned flat surface and measuring the electrical conductivity between the conductors with electrical differential of 1250 V. A computer collects data on the absolute position of the conductors on the core (the position is converted into depth) and on the current passing between the conductors (μA or mA). This measure is proportional to the acid content of the ice. Therefore, it virtually represents the chemical content of the cores. Although this is not a quantitative measure, it permits rapid acquisition of data (50 m of core in 2 days) on the chemical charge of the ice cores. The high resolution of these analyses (between 1 and 3 mm) makes it possible to identify high concentrated and limited events in time. More specifically, the volcanic acid levels and levels of acidity related to anthropic activities are revealed through these tests. The test made on the first 60 m revealed a clear decrease in conductivity towards the surface (fig. 4).

This can be attributed both to the change in density with the depth and to the acidity drop, due mainly to the decrease of anthropogenic sulfates emitted into the atmosphere starting from the late 1970s, that is, following the improvement in the quality of the gasolines and fuel oils used for vehicles, heating systems and the production of electricity, the lower emission levels of sulphates produced by industrial plants and the conversion of electrical power plants from coal-fuel oils to gas (e.g. methane). Several peak of conductivity found in the profile can be traced back to particularly intensive events involving emissions of anthropogenic acids (prevalently S), although the possibility of volcanic eruptions of the explosive type also contributing cannot be excluded. In particular, the conductivity peak present at a depth of 21 m w.e. (exceeding 150 μA, three times the background level could be related to the large-scale eruption of El Chichon, which took place in Central America in 1981. The Saharan dust events are also detectable using the ECM method. The high calcium ion (Ca^{++}) content in the dust has the capacity to buffer the acidity of the ice and thus reduce the signal to minimum levels, nearing zero.

CONCLUSIONS

The initial results of the analyses conducted on the CG1/95 and CDL1/96 reveal a marked difference in net accumulation levels, in spite of the fact that the two sites are very near to each other (with a distance around 3 km, and 200 m difference in altitude). In fact they reached depths that differed considerably, but the two coring operations covered the same span of time (about 50 years). Another particularly interesting aspect is that although the accumulation levels differed greatly, the records obtained show high similarly in the trends of natural and anthropic sources over time. In fact, the chronology of the two cores was reconstructed starting from the same events. The tritium peaks of 1963 and 1957 were present in both cores, as was the level of Saharan dust of 1977.

Another interesting point is the presence of the high peak in the ECM record, at 21 m w.e., which is perhaps attributable to the explosive eruption of El Chichon in 1982. Unfortunately we have no ECM record for the CG1/95. In any case, this latter reference horizon could be checked with chemical analyses to determine its origin. In conclusion, it can thus be stated that both cores have supplied information of marked importance. On the one hand, at Colle Gnifetti, the lower accumulation rate offers the possibility of supplying data series longer than a century through deeper drillings (Wagenbach, 1989; Maupetit &

alii, 1995). The latter would provide an indication as to the trends and evolution of the chemical and physical composition of the atmosphere for that period. On the other hand, at Colle del Lys where accumulation was clearly greater, we find the potential for a detailed analysis of the climatic and environmental characteristics of the last 50 years, with a seasonal breakdown that is capable of detecting individual cases of snowfall.

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