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SCAR WORKING GROUP ON GLACIOLOGY

REPORT ON ITALIAN ACTIVITY
2001-2002

ITALIAN GLACIOLOGY RESEARCH

This report covers the two-year period from the last meeting in July 2000 until the present (July 2002). During this period, the Italian Antarctic Research Programme (PNRA) has continued to operate and promote glaciological research in Antarctica, as part of the core project "Glaciology". Part of the research has been carried out at Dome C in the framework of the French-Italian Concordia project and of the European Program for Ice Coring in Antarctica (EPICA). A significant effort, both from the logistic and scientific standpoint, has been exerted in co-operation with other partners, in international project such as EPICA, IT ASE, Subglacial Lake and others scientific initiatives.

EPICA

EPICA is a long-term project for ice coring in East Antarctica in two different sites, Dome C on the Pacific-Indian sector, and Dronning Maud Land on the Atlantic sector. EPICA is financially supported by national contributions from ten European countries and by EU funds, and is supported by the European Science Foundation.

We continued to contribute to EPICA with scientists working in the field at Dome C (123°24'E, 75°06'S) on the East Antarctic plateau. 2001 and 2002 were the fifth and sixth deep drilling seasons at Dome C. The drilling reached a depth of 2871.1m during the last season. The scientific contribution has been mainly dedicated to *in-situ* semi-continuous measurements on the ice cores (Fast Ion Chromatographic), and in the collaboration in the Italian laboratories to the analyses of dust, other chemical components, trace elements and oxygen stable isotopes. A complete data set of chlorine, nitrate and sulphate has been produced up to the depth of 2162.05 m, encompassing about the last 215 ka. Oxygen isotope measurements, deuterium excess values, insoluble dust concentration and particle size distribution has been analyzed along the last 45 ka (obtained together with French partners).

Highly detailed deuterium excess profile measured along the Dome C EPICA core infer that an Oceanic Cold Reversal took place during deglaciaton in the southern Indian ocean, 800 years after the Antarctic Cold Reversal, and that a similar situation occurred at the end of the early Holocene optimum, about 9 ka BP. The temperature gradient between the oceanic moisture source and Antarctica shows remarkable similarities with the Dome C sodium profile during the deglaciation, illustrating the strong link between this gradient and the strength of the meridional atmospheric circulation.

FIC analysis performed in field on the first EPICA Dome C ice core (EDC96)

provided analyses of high resolution profiles for Cl^-, NO_3^-. and SO_4^{2--}, spanning the last 45 ka. The determined chemical markers exhibit a well defined decreasing trend from the highest levels recorded in the Last Glacial Maximum (LGM) to the low and stable Holocene values with a low (chlorine) and no (nitrate and sulphate) sensitivity to Antarctic Cold Reversal (ACR) climatic change. Holocene sulphate and chloride profiles of EDC96 ice core were compared with the corresponding electrical conductivity (ECM) and dielectric profiling (DEP) measurements revealing an excellent fit, mostly for peaks related to volcanic emissions (obtained together with UK partners). A tentative age scale (EDC1) for the last 45 ka was established for the EDC96 ice core using an ice flow model and calibrating the model parameters through the age of volcanic eruptions, the end of the Younger Dryas event and the estimated depth and age of elevated ^{10}Be (about 41 ka). The uncertainty of EDC1 is estimated to ± 10 yr for 0 to 700 yr BP, up to ± 200 yr back to 10 ka BP, and up to ± 2 ka back to 41 ka BP.

Insoluble dust concentrations and volume-size distributions have been measured for the new 581 m deep Dome C-EPICA ice core (Antarctica). Over the 27 ka spanned by the record, microparticle measurements from 169 levels, to date, confirm evidence of the drastic decrease in bulk concentration from the Last Glacial Maximum (LGM) to the Holocene (interglacial) by a factor of more than 50 in absolute value and of about 26 in flux. Unique new features revealed by the EPICA profile include a higher dust concentration during the Antarctic Cold Reversal phase (ACR) by a factor of 2 with respect to the Holocene average. This event is followed by a well-marked minimum that appears to be concomitant with the methane peak that marks the end of the Younger Dryas in the Northern Hemisphere. Particle volume-size suggests different modes of transport prevailed during the two climatic periods with easier penetration of air masses into Antarctica in the Holocene than during Glacial times.

ITASE

As apart of lTASE (International TransAntarctic Scientific Expedition) the Italian Antarctic Programme conducted a traverse and spot research at selected sites (AWS, firn core, stake farms) for analyses of time variability of precipitation and the redistribution process.

The objectives of the research are to develop an understanding of the latitudinal and longitudinal gradient, along three transept East-West (Terra Nova Bay -Dome C, Taylor Dome - Dome C and Talos Dome - D66) and two transept North-South (Dumont d'Urville -Dome C and GV7 -Talos Dome -Taylor Dome), documenting the last 200-1000 years of the climatic, atmospheric and surface conditions over the Eastern and NE

Dome C drainage area and the Northern Victoria Land. Traverse and Twin Otter activity were performed in collaboration with French colleagues. The traverse took place along Adélie, George V, Oates and Northern Victoria Lands between 3 November 2001 and 16 January 2002. The distance covered was about 1875 km. Eighteen shallow snow-firn cores, up to 55 m in depth, were drilled. Eight snow-pits were also dug, up to two metres in depth, to investigate snow stratigraphy, density and for chemical and isotopic analysis. One-metre-deep drill holes were made along the traverse every 5 km (363 samples) for chemical-isotopic analysis. Stake farms were installed and measured using GPS, to study variability of snow accumulation and submergence velocities. Stakes for ice velocity were measured by GPS at 30 sites. Snow radar (GPR) and GPS surveys over a distance of3245 km were conducted in order to link core sites, provide detailed information on spatial variability in snow accumulation and to provide a detailed description of Talos Dome area. A spatial distribution survey of the micro-relief surface type, size and orientation was conducted along the traverse. Three hundred forty gravity and magnetic stations, supplemented by airborne radio-echo sounding, were acquired along the 3000-km-long traverse.

Field observations (GPS, GPR, and surface measurements) along the ITASE traverse have provided a detailed description of megadune sedimentation and morphology over a 70km^2 area, located 200 km East of Dome C. A combination of remote sensing analysis and field measurements indicate that slope in the prevailing wind direction and climatic conditions play a crucial role in megadune genesis. The megadunes formed by variable net accumulation, ranging between 25% (leeward faces) to 120% (windward faces) of the accumulation in adjacent non-megadune areas. Megadune fields occupy large areas in the interior of the East Antarctic ice sheet and are the result of unusual snow accumulation and redistribution processes. They therefore are important to surface mass balance and ice core interpretation.

The δD and nss SO_4^{2-} record obtained from the Talos Dome core has been compared with other East Antarctic isotope ice core records (Dome C EPICA, South Pole, Taylor Dome). These records suggests cooler climate conditions between the middle of the 16th and the beginning of 19th centuries, which might be related to the Little Ice Age (LIA) cold period. Due to the high degree of geographical variability, the strongest LIA cooling was not temporally synchronous over East Antarctica and the analysed records do not provide a coherent picture for East Antarctica. The accumulation rate record presented for the Talos Dome core shows a decrease during part of the LIA followed by an increment of about 11% in accumulation during the 20th century.

Results of chemical, tritium and stable isotope composition collected along the

Terra Nova-Dome C traverse show that the $\delta^{18}0$ values show a regular trend with altitude and the regression line between $\delta^{18}0$ and surface temperature is $\delta^{18}O = 0.99\ T\ (°C) -0.67$. Primary aerosol components (Na^+, $C1^-$, Ca^{2+}, Mg^{2+} and K^+) show high concentrations decreasing with increasing altitude in the first 250-350 km from the coast. NO_3^- concentration shows an irregular profile with a progressive decreasing trend as altitude increases. Non-sea-salt (nss) SO_4^{2-} concentration decreases up to about 250 km from the coast, increases in the successive 250-770 km and remains relatively constant in the most remote stations. The MSA/nssSO_4^{2-} ratio exhibits a decreasing trend between 250 and 550 km from the coast, with increasing distance; the ratio shows moderate oscillations. Post-depositional re-emissions of $C1^-$ and NO_3^- were pointed out in stations characterised at the surface by long-term accumulation hiatus (wind crusts).

Determinations of trace metals (obtained together with European partners) revealed that atmospheric pollution for heavy metals in the remote Antarctic continent is not limited to Pb and Cu, as previously thought, but also includes several other metals, a further indication that atmospheric pollution for heavy metals is truly global..

SUBGLACIAL LAKE

During the 2000-2001 Italian Antarctic Expeditions, extensive airborne radar surveys were carried out over the region Vostok-Dome C-Talos Dome (about 7300 km of radar profiles were acquired). A new radar was tested, operating at 60 MHz, 16 MHz bandwidth, acquiring 10 trace/sec (1 trace/6-8m), with a pulse length variable between 0.125 μs. The radar data were used to determine the ice thickness and the bedrock topography over the entire area; in addition, the analysis of the shape and the amplitude of the bottom reflections, identified 30 radar profiles as sub-glacial "lake" mirrors. The comparison of the radar data with the surface and bed anomalies showed 14 new possible lakes around Dome C. Two of the new lakes, located N-E of Dome C, into the Vincennes Basin, are of interest because of their size, (more than 1000 km^2 in area). Aside from Lake Vostok, the lakes would be the next largest discovered to date in Antarctica.

Analysis of Vostok Lake airborne radar surveys confirms the geometry derived by the past surveys, with some slight differences: we measured a length up to 260 km and a maximum width of 81 km, so it is likely that the area is greater than calculated earlier. The ice surface and the bed slopes confirm the model of ice in hydrostatic equilibrium. Analysis of the internal layers showed distinct melting (restricted only along the entire western margin) and freezing zones, and a wide continuous area without freezing or

melting along the entire North-South lake axis. An almost symmetrical structure of the lake was obtained, characterized by a wide and continuous area, located along the major axis of the lake, of non melting or freezing surrounded, west and east, by relatively narrow areas of freezing.

METEORITE TRAP

Field collecting during 2001-2002 in the Outback Nunataks blue ice fields (Northern Victoria Land) produced 174 meteorite specimens with the largest as much as 6.2 kg in weight. Remote sensing analyses and field campaigns have furnished new glaciological data on ice flow, ice thickness, bedrock topography, ice ablation and surface mass transport by wind, along with detailed descriptions of the field situation at the Frontier Mountain trap. These data, combined with an updated meteorite distribution map and terrestrial ages available from the literature, has resulted in a better understanding of the concentration mechanism. In particular, we found that the meteorite trap forms in a blue ice field located upstream of shallow sub-ice barriers, resulting in compressive ice flow with horizontal velocities decreasing from 100 to <10 cm a^{-1} on approaching the obstacle. The ice undergoes; mean ablation rates of 6.5 cm a^{-1}, and is nourished by a limited snow accumulation zone extending 20 km upstream of the blue ice area.

ANTARCTIC PERMAFROST

Permafrost and periglacial processes have been investigated in Northern Victoria Land. Through monitoring stations the importance of snow cover and vegetation over the permafrost thermal regime has been outlined. A systematic analysis of periglacial forms and types of ground ice revealed the presence in Antarctica of forms such as frozen heaved mounds and/or pingos, ice wedges, and other patterned ground features. Boreholes in permafrost have been monitored for thermal variations.

GLACIAL GEOLOGY -GEOMORPHOLOGICAL AND GLACIOLOGICAL MAPS

Studies in glacial geomorphology were conducted, with objectives to reconstruct, Late Quaternary glacial history, map the Last Glacial Maximum ice extent and Late Glacial and Holocene moraines. Late glacial and Holocene fluctuations were recognised and partly dated. Detailed and regional geomorphologic and glaciological mapping resulted in a new map at a scale of 1:250,000 (Relief Inlet quadrangle) other maps are in print.

The main Italian institutes, which are involved in glaciological field programs in Antarctica, are the following

Progetto Cliima: ENEA Roma
Dip. Chimica: Univ. Firenze
DiSGAM; Univ. Trieste
DSA Univ. Venezia
DISAT: Univ. Milano-Bicocca
DST: Univ. Milano
DST: Univ. Parrna
DST: Univ. Siena
DlSTART: Univ. Bologna
INGV: Roma

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