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EDITED BY

S. MUKHERJEE
Indian Institute of Technology Bombay, India

R. CAROSI
University of Torino, Italy

P. A. VAN DER BEEK
Université Grenoble Alpes, France

B. K. MUKHERJEE
Wadia Institute of Himalayan Geology, India

and

D. M. ROBINSON
University of Alabama, USA

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In memory of Bruno Lombardo (1944–2014)

This Special Publication pays tribute to Bruno Lombardo whose sudden death occurred in January 2014 after a short illness. A Senior Research Fellow at the Italian ‘Consiglio Nazionale delle Ricerche’ (National Research Council – CNR), Bruno was an outstanding example of a geologist who combined detailed field observations with a deep knowledge of petrology.

Bruno Lombardo was born on 15 December 1944 in Cuneo, NW Italy, facing his beloved Alpine mountains. He graduated in Geology at the University of Turin in 1970 with a thesis on the Gran Paradiso Massif, a prominent ‘four-thousander’ and one of the Internal Crystalline Massifs of the Italian Western Alps. After a short fellowship at the then ‘Institute of Mineralogy and Petrography’ at the University of Turin, Bruno joined the staff of the CNR in 1972 in the present-day ‘Institute for Geosciences and Earth Resources’, remaining there until his retirement in 2007.

His background in petrology and field geology led him to devote his research efforts to the orogenic belts of northern Italy, Antarctica and the Himalayan countries. Since his thesis work, a major subject in Bruno Lombardo’s research was the crystalline rocks of the Western Alps, with fundamental studies on the origin and metamorphic evolution of the Internal Crystalline Massifs, the External Crystalline Massifs, the Sesia Zone and the Piemonte Zone. His contributions on Alpine geology ranged from studies in mineralogy and petrology to geochemical, geochronological and tectonic studies, reflecting his eclectic personality.

Bruno Lombardo’s interest in eclogite-facies rocks led to the publication of many papers on high-pressure metamorphism in the tectonic units of the Western Alps (Sesia Zone, Gran Paradiso Massif, Dora-Maira Massif, Argentera Massif) derived from continental crust. Bruno was also interested in the origin and evolution of the ophiolitic rocks of the Western Alps: his studies on the Monviso Massif have been a reference for generations of geologists and still represent the fundamental starting point for any fieldwork activity in the area.

Bruno Lombardo was able to disseminate his wide knowledge not only to students but also to non-expert public groups, guiding them in the field and explaining difficult geological concepts in easy but effective ways. Following this spirit, he actively collaborated with mineral collectors publishing a number of volumes dedicated to the minerals of the Western Alps in recent years.

Another milestone of Bruno Lombardo’s scientific activity dates back to 1985, when he joined...
the first Italian Antarctic Expedition to Northern Victoria Land. He also joined the second and fourth expeditions and, thanks to his great skill and experience, made significant contributions to modelling the petrological and metamorphic evolution of the Wilson Terrane in Northern Victoria Land and its relationships with the East Antarctic Craton. During this pioneering time of Italian research activity in Antarctica, Bruno was appointed project leader of the Basement Rocks Petrology, Geochemistry and Geochronology division of the PNRA (National Antarctic Research Programme), as well as a member of the CNR Polar Board.

The origin of the third major subject of Bruno Lombardo’s research work can be traced back to 1975 when he was invited to join the Italian Alpine Club (CAD)–CNR mountaineering expedition to Lhotse south face, in order to study the Higher Himalaya and the Tibetan Series exposed in the Khumbu region of eastern Nepal. Some of the best Himalayan climbers (including Reinhold Messner) were part of the team. Although the extremely difficult Lhotse south face was not climbed, the outstanding mountain scenery and the fascinating geology around the ‘eight-thousanders’ lured Bruno to devote most of his scientific skill to the study of Himalayan regional geology and tectonics.

Bruno came back to the Himalaya some sixteen times over more than 30 years, mainly to investigate the geology and metamorphic evolution of the Greater Himalayan Sequence and Main Central Thrust Zone in eastern Nepal (Everest and Makalu region) and southern Tibet (Rongbuk and Cho Oyu region, Upper Arun and Kharta Valley, Lago Kangri dome) as well as further east in Sikkim and the Bhutan Himalaya. Bruno was also involved in geological exploration in the northwestern Himalayan countries, either taking part or leading reconnaissance expeditions in India (Zanskar) and Pakistan (Nanga Parbat–Haramosh Massif, Chogo Lungma Glacier, Deosai Plateau and Hunza Valley).

Bruno published over 25 papers and numerous conference abstracts on many geological and petrological aspects of the Himalaya. He was extremely capable and collaborated with numerous colleagues, all experts in different aspects of Earth Sciences, in order to get most of the answers his ever-curious mind was searching for. Among the most significant results he obtained, a few are mentioned below.

Following Bruno’s early fieldwork in 1975, the petrography and geological setting of the Higher Himalaya and the Tibetan Series on the Nepalese side of the Lhotse and Everest area was described, with special reference to the upper Imja Khola (Bortolami et al. 1976, 1977). Close co-operation with Italian geochronologists and geochemists produced some of the first dating of granites and gneisses from the Mount Everest region (Ferrara et al. 1983), as well as the Sr, Nd and O characterization of the Gophu La and Gumbaranjun leucogranites of the High Himalaya (Ferrara et al. 1991), and the isotopic characterization of partial melting in the Namche Migmatite of the Khumbu Himal (Tonarini et al. 1994). In the mid-1980s his long-lasting co-operation with the petrology group of the University of Torino, Italy, began producing petrological data on the Gophu La and Western Lunana Miocene muscovite leucogranites of the Bhutan Himalaya (Castelli & Lombardo 1988).

After his first field season in NW India, the metamorphic evolution of the High Himalayan Crystallines in SE Zanskar was described in collaboration with his late colleague Ugo Pognante (Pognante & Lombardo 1989). By combining fieldwork, structural analysis and geothermobarometry, Bruno published data on the geology and tectonomagmatic evolution of the eastern Himalaya along the Chomolungma–Makalu transect (Lombardo et al. 1993), introducing his most welcome ability to link field data with an uncommonly deep knowledge of regional geology.

A new season of exciting work started in 1993 with a joint Italian–French expedition to Baltistan, with the late Patrick Le Fort being part of the team. The Himalaya–Karakorum junction in the Chogo Lungma Glacier area was eventually mapped (Le Fort et al. 1995) and the tectonometamorphic evolution of the southern Karakorum metamorphic series (Lemennicier et al. 1996) and of the Ladakh arc units (Rolfo et al. 1997) were described.

In the meantime, Bruno’s interest in the Everest–Makalu region, both in Nepal and Tibet, was still lively, with active co-operation from the structural geology group of the University of Pisa, Italy. This led to description of the deformation features of the South Tibetan Detachment System in the Rongbuk valley and their geological implications (Carosi et al. 1998); the same approach was used on the Higher Himalayan Crystallines in Khumbu Himal (Carosi et al. 1999).

Also because of his long-lived interest in high pressure metamorphism in the Italian Western Alps, Bruno was always attracted by the few elusive eclogites exposed in the Himalaya. He described the petrology of glaucophane and barroisite eclogites from the Upper Kaghan Nappe of northern Pakistan and discussed their implications for the metamorphic history of the northwestern Himalaya (Lombardo et al. 2000). Later, while studying the P–T evolution of garnet granulites from the Kharta region of southern Tibet (Borghi et al. 2003), he discovered and described the petrologically complex granulitized eclogites exposed...
in the Ama Drime range of the east Himalaya, pointing out the contrasting nature of high pressure metamorphism in different sectors of the Himalaya (Lombardo & Rolfo 2000) and revealing their exhumation path and fluid evolution (Ferrando et al. 2007; Groppo et al. 2007).

Beside his profound interest in the metamorphic evolution of the studied units, he was also extremely interested in the magmatic history of the famous Himalayan leucogranites, widespread in the areas he visited. In collaboration with the University of Padua, Italy, he studied the two-mica and tourmaline leucogranites of the Everest–Makalu region and speculated on their genesis (Visonà & Lombardo 2002).

The last field season in his beloved Arun Valley in 2006, just before his retirement, enabled him to cross the Main Central Thrust Zone once more and to perceive the beginning of a new exciting season of research, with high-resolution petrology revealing previously unreported hidden discontinuities (Groppo et al. 2009) and new SHRIMP geochronological data, obtained in collaboration with colleagues from the Australian National University in Canberra, on Early Oligocene partial melting in the Main Central Thrust Zone (Groppo et al. 2010).

Bruno had a continually questioning and brilliantly encyclopaedic mind. His unbelievable memory was much like that of a computer and virtually everything he used to read remained indelibly carved in his mind. Moreover, this natural gift was well coupled with a passion for books; the walls of his house were literally covered by several thousand books on geology, mountaineering, travel and local history. This trait was much welcomed by his many colleagues, who visited him asking many questions about mountains, regional geology and the tectonics of almost any place in the world. So, doing fieldwork with him was somehow easier as it was a bit like carrying a whole Earth Sciences library with the team. Bruno also had the incredible capability of travelling first with his mind and then with his feet; he was able to imagine and describe in great detail any itinerary in both the Alps and the Himalaya, even if he had never been there. His colleagues still working in both the Himalaya and the Alps will surely miss his precious suggestions.

It is clear that, through all his life and research work, Bruno Lombardo was able to develop a vast network of scientific collaborations and relationships. It is nice to point out that he was able to transmit his passion for Himalayan studies to a number of younger researchers, who will try their best to pursue this intellectual heritage. His wife, daughter, grandchildren, colleagues and his many friends will miss such a good, intelligent, tenacious, learned, calm and curiosity-driven life and a wonderful research companion.

FRANCO ROLFO

Chiara Groppo

Rodolfo Carosi

References


Himalaya–Karokorum junction in Chogo Lungma to Turmik area (Baltistan, Northern Pakistan). Journal of the Nepal Geological Society Special Issue, 11, 17–38.


In memory of Patrick Le Fort (1939–2014)

Patrick in the field in the Buhri Gandi Valley (Central Nepal) during the spring of 1990.

This Special Publication pays tribute to Patrick Le Fort who passed away in February 2014 after a long illness. A Senior Research Fellow at the French National Research Council (CNRS), Patrick was an outstanding Himalayan geologist who combined detailed field observations with a deep knowledge of petrology.

Patrick was one of the major internationally recognized scientists in the French team of Himalayan geologists. He studied at the famous geological school ‘Ecole Nationale de Geologie de Nancy’ and received his diploma in 1962. He then joined the CNRS, in charge of research at the Nancy Centre of Petrography and Geochemical Research (CRPG). An excellent mountaineer, he enthusiastically undertook a thesis proposed by P. Bodet on the geology of the southern part of the Pelvoux crystalline massif. His descriptions and interpretations are still valid today.

Since 1950, when French mountaineers climbed Annapurna I and brought back fossils, mountaineers have been encouraged to include scientific participants in their expeditions. P. Bordet and M. Latreille were associated with the Makalu expeditions (1954–55). This induced P. Bordet to organize a geological field trip to the Thakkhola area (1963) which led to this area being recognized as being of major geological importance. A second Thakkhola field trip was organized in 1966 and P. Bordet invited two young geologists to join the team. It was the beginning of Patrick and M. Colchen’s geological adventures in the Himalaya. Later, new field missions were organized in Marsyandi (1969) and north of the Manaslu massif (1971). The detailed results were published by the CNRS in 1971 and 1973, and a global synthesis was published in 1986. During a sabbatical year at Harvard (USA) in 1975, Patrick wrote and published in the American Journal of Science a fundamental paper: ‘Himalaya: the collided range. Present knowledge of the continental arc’, which placed the Himalayan belt within the (then) new paradigm of plate tectonics, and is still today a classic reference paper for Himalayan geologists. In 1975, Patrick was awarded the CNRS Silver Medal.

It is difficult to summarize Patrick’s very rich geological career. We will touch on only a few major aspects here. Patrick was absolutely convinced of the importance of collaborative research. During the years 1960–70, he was a major player in the multidisciplinary research of the CNRS teams in the Himalaya (‘RCP Nepal’, then ‘GRECO Himalaya–Karakorum’). One of his main satisfactions was to be in the field with colleagues from very different scientific specialities (ecologists, ethnologists etc.). In the same way, Patrick promoted many collaborative projects with universities in Europe, Nepal, Pakistan and the USA when he was Associate Professor at Harvard (1985–86). In 1985, he was, e with Mike Searle, the founder of th Himalaya–Karakorum–Tibet (HKT) workshop. The first meeting was organized in Oxford by Mike Searle, the second one in Nancy was organized by Patrick. All know how successful this initiative has been.

Patrick was a field geologist, convinced that careful observations were the basis of all scientific results. He participated in completion of a number of geological maps (Central Nepal 1/200,000 with M. Colchen and A. Pêcher in 1986; West Karakorum with M. Gaetani in 1988; Hunza–Baltistan with A. Pêcher in 2002). His field notebooks are very detailed and precise. In 1976, with J. Malbos, past President of the CAF (Club Alpin Français), and M. Fort (geomorphologist), he reorganized the CAF Scientific Committee. Encouraged by Patrick, the CAF organized mixed alpinist-scientific expeditions to Biafo-Hispar (1984), Pumori-Chish (1988), Kula-kangri (1988), and Himlung-Himal (1997).

Patrick was also a laboratory man. A collaborator of H. De La Roche at the CRPG, he worked on the geochemistry of granites in crystalline massifs.
in the Alps, in Portugal and Spain, and in the Himalaya to model the crustal origin of leucogranites. The Debon & Le Fort diagram (Debon et al. 1986) is now a classic tool for characterizing granites.

Patrick was also a geoscientist who synthesized results into over-arching models, and often a promotor of revolutionary new ideas. In 1975 he published his famous model of Himalayan reverse metamorphism (the 'hot iron model'), later numerically improved with the help of P. England, P. Molnar and A. Pécher (1992). In 1987, Patrick published, with S. Sheppard and C. France-Lanord amongst others, a model for formation of the Himalayan leucogranites by hydration of the High Himalayan gneisses. In 1982, after a memorable scientific polemic, he demonstrated with P. Vidal and A. Cocherie that the Manaslu leucogranite was isotopically heterogeneous as a result of forming from multiple magmatic intrusions derived from the melting of heterogeneous gneisses. Later, with P. Vidal, C. Deniel, A. Fernandez and J. J. Peucat (1987) he obtained the first robust dating of the young Manaslu leucogranite (17 to 24 Ma).

Additionally, alone or more frequently associated with first-class colleagues, Patrick participated in the education of numerous students, either French (C. France-Lanord, B. Scaillet, M. Brouand, S. Guillot, Y. Lemennicier), Nepali (B. N. Uperti, S. M. Rai, A. P. Gajurel) or Pakistani (A. B. Kausar). They remember his enthusiasm, his working capacity and the robust nature of their scientific discussions.

In 1990, Patrick came to Grenoble, joining the Himalayan group, and here he remained until the end of his scientific career. The 1997 Himalung-Himal CAF expedition, with S. Guillot, was his last field mission, resulting in publication of the cartography of the Manaslu massif (Le Fort & Guillot 2000), a personal completion for Patrick who had passionately studied this massif for 25 years.

Patrick then went on to undertake a new career in diplomacy. He was the CNRS representative and Scientific Councillor in South Africa for 4 years, then representative of the CNRS International Bureau in Moscow, also for 4 years. After his retirement (2008) he returned to the house in Boni-paud, isolated in the Sauveterre Causse, which had become his family home, in the company of his grand pianos, his second passion.

References


