J Paleolimnol (2014) 51:139–144
DOI 10.1007/s10933-013-9699-5

NOTES

Reminiscences and acknowledgements from a lover of deserts near the end of her professional life

Françoise Gasse

Received: 19 January 2013 / Accepted: 20 February 2013 / Published online: 26 May 2013

Abstract Following the IPS-2012 Symposium where I received an award medal for « my lifetime achievements », this is a short note where I explained when, how and why I became interested in paleolimnology. I am grateful to the many people with whom I have worked.

Keywords Lakes and paleolakes · Africa · Western China · Diatoms · Stable isotopes

I was very pleased and honored to receive an IPS-2012 award for "my lifetime achievements" in paleolimnology, following the kind introductory words of my colleagues and friends, Rick Battarbee and Sherilyn Fritz. I first want to say that these achievements were largely due to the many people with whom I have collaborated and to some good luck. In fact, when it was time to select a job direction, I was very hesitant, having to decide between artistic endeavors and science. Today I am most grateful to those who opened doors for me to the geo- and hydro-sciences, including my specific tool, diatoms, and to numerous colleagues and students from various fields. I cannot cite them all in this short note, but they have enriched my professional experience and many are still my good friends. My good fortune also took me to very diverse types of waterbodies, from sub-equatorial, large, deep freshwater rift lakes, to groundwater-fed, hypersaline sebkhas in arid lowlands, to very high alpine lakes. This diversity helped me understand the complexity of the interacting factors, climatic or not, that control a lake's behavior and evolution through time, in response to changes in its drainage basin.

How I became interested in paleolimnology and diatoms

I am primarily a geologist, although I have been a lecturer in Botany (Ecole Normale Supèrieure, Fontenay-aux-Roses) for almost two decades. I would have preferred a position in Earth Sciences, but my teaching experience familiarized me with taxonomy and ecology, useful topics for paleobiology. While teaching, I undertook a dissertation in Geology in 1970, which I completed in 1975. I joined the Laboratory of Quaternary Geology, close to Paris, thanks to its director, Professor Henriette Alimen, a delightful specialist on the prehistory of North Africa. I rapidly became involved in a geologic field trip to the

The author was the recipient of a ''Lifetime Achievement Award'' presented by the International Paleolimnology Association (IPA) in Glasgow, Scotland on 22 August 2012.

F. Gasse (✉)
CEREGE, UM34 Aix-Marseille Université—CNRS (UMR 7330)—IRD (UMR 161), 13545 Aix en Provence, France
e-mail: gasse@cerege.fr

Afar depression (Ethiopia, Djibouti), one of the driest and hottest regions in the world, and an exceptional area for Quaternary volcanic and tectonic activity. My interest in paleolimnology and paleohydrology definitely awakened there, when, after 15 days on terrible roads through rocks and sand, we arrived at the remnants of large lakes, diatom-rich sediments with fossil fish, harpoons and other artifacts, attesting to the fact that another world had once existed there. When and why had these lakes developed? What was the source of their water? When was this area hospitable for human populations? How do the few nomadic inhabitants who live there today survive in such a harsh environment? These questions directed my research activities for decades. And throughout my professional life, I have used lake archives to reconstruct and understand Quaternary changes in climate and water resources in arid and semi-arid zones of Africa and western Asia.

The Afar was an excellent "school" in which to learn about the influence of structural and geomorphic evolution on the temporal and spatial distribution of paleolakes, but I was still a novice in Quaternary African environments and climate. I suspected that diatoms could be powerful tools for investigating paleoclimate and paleoenvironment, but I only knew that these abundant fossil organisms were microscopic algae with a siliceous test. Fortunately, in Paris,

Fig. 1 Working on diatoms at the CEREGE

Professor Pierre Bourrelly, an algologist at the Museum d'Histoire Naturelle, quickly passed on to me his enthusiasm for diatom study (Fig. 1) and he remained a great help to me for many years. Professor Jean-Paul Benzecri, a famous specialist in data analysis at the Statistics Institute, Paris University, and his PhD student Fredj Tekaia, initiated me into the world of statistics for sorting my diatom results into biostratigraphic and paleoenvironmental groups, from the Plio-Pleistocene to recent. Well preserved paleo-shorelines, lithofacies and diatom analyses, supported by radiometric dating (^{14}C dates and K/Ar ages of volcanic flows bracketing lake sediments), demonstrated the spectacular amplitude of Quaternary lake-level, volume and salinity fluctuations in the deepest tectonic basins of the Afar desert. For example, Lake Abhé, today a small, shallow, hyper-alkaline waterbody, was a 160-m-deep freshwater lake that extended over 5,000 km^2 during the early to middle Holocene (Gasse 1977) (Fig. 2).

Professor Alayne Street-Perrott, University of Swansea, and I compared our results from the Ethiopian Rift Valley and Afar lakes (Gasse and Street 1978), with those just made available from the Chad basin. The remarkable synchrony in hydrological fluctuations over the past 30 ka clearly revealed the common factor that drove this evolution: climate and monsoonal rainfall variability in the North African tropics. I benefited greatly from collaborations with Alayne and Professor Martin Williams (Adelaide University) on further paleoenvironmental and biostratigraphic work in the Afar and Ethiopia (Williams et al. 1979; Adamson et al. 1980; Fourtanier and Gasse 1988). Indeed, Martin invited me to Australia in 1987 to promote diatom studies there, an objective realized with great success, in that I had a chance to mentor Peter Gell, now Professor at the University of Ballarat.

Diatom-based transfer functions

The need to quantify diatom-inferred environmental changes and to relate them to climate change was obvious. A database of living diatoms and associated ecological variables became a fundamental requisite. I thus visited, along with my husband and young daughters, a number of very diverse East African waterbodies in Djibouti, Ethiopia and Kenya, ranging

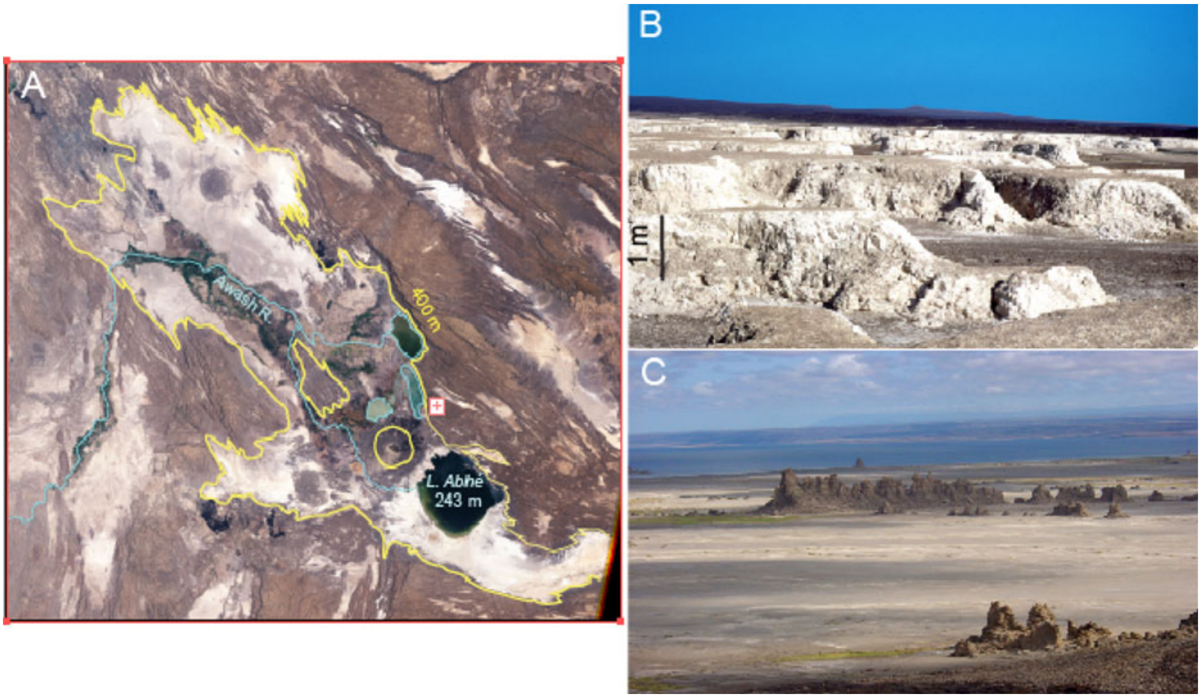

Fig. 2 **a** The lake Abhé basin. *Yellow curve*: early-middle Holocene paleoshoreline. *Dark green areas*: swamps and residual lakes supplied by the Awash River. **b** Paleolake Abhé sediments (calcareous diatomite) close to the northern edge of the basin (~390 m a.s.l). **c** The SW lake margin (~245 m). Emerging from the clayey mud, the carbonate edifices (20–60 m high) aligned along faults are of hydrothermal origin. They were formed under water during a last lake highstand of moderate amplitude (late Holocene). (Color figure online)

from 150 b.s.l. to 4,500 m a.s.l. I obtained additional samples from southern East Africa lakes, courtesy of Professors Jack F. Talling and Peter Kilham. It appeared that, in addition to depth and turbidity, the major factor controlling diatom assemblages was water chemistry (Gasse et al. 1983). The first transfer functions for inferring lake water chemistry, pH and salinity in East Africa were constructed (Gasse and Tekaia 1983). Later, in collaboration with PhD students L. Ben Khelifa, N. El Hamouti, A. Ben Khaddour and R. Téhet, the Maghreb and West Africa datasets were merged with the initial database. New transfer functions, based on about 400 diatom taxa from 290 sites, were established, thanks to Steve Juggins (University of Newcastle), for reconstructing pH, conductivity and ionic ratios in African lakes, at least north of the Equator (Gasse et al. 1995).

Diatoms, however, are sometimes absent from lake sediments, and diatom-based reconstructions can be equivocal. Post-mortem diagenesis and selective dissolution may significantly bias counts, as shown by experimental dissolution of diatom silica in salt solutions of various concentrations and different chemical types, conducted with my long-term collaborator, Professor Philip Barker from Lancaster University (Barker et al. 1994). In addition, taphocoenoses only represent the short lifetime of the diatom, e.g. one season. Too little monitoring of tropical lakes has been done, in most cases, to document seasonal to interannual changes in hydrological parameters, which can be large in these regions of high climatic variability.

Integration of multiple proxies in different regions

Multi-proxy and cross-checking approaches help avoid misinterpretation and provide more comprehensive insights into past environmental changes. Working at large spatial scales is also required to understand monsoon variability and paleoclimate in the tropics and subtropics.

I am extremely grateful to my close friend, Professor Jean-Charles Fontes, who trained me in hydrology and isotope geochemistry. Sadly, he died in an accident during an IAEA field trip in Mali in 1994. When I entered the CNRS and joined his lab (Hydrology and Isotope Geochemistry, Paris-Sud University) in 1986, I really started to integrate water and carbonate stable isotopes into my work and realized the importance of groundwater fluxes in controlling water, salt and isotope balances in lakes. I also became more critical and rigorous in the interpretation of radiocarbon dates, and radiogenic dating in general. The combination of water and sediment isotopic data with diatom-inferred hydrochemical variables helped us considerably to understand the hydro-system functioning of lakes and paleolakes and identify the rainwater source (monsoonal or extra-tropical). This was done especially in the Shara-Sahel (Fig. 3; Gasse et al. 1990) and, in collaboration with our friend Professor Wei Keqin (Guanzhou University) in western China (Tibet and northern Xinjiang) (Fontes et al. 1993; Rhodes et al. 1996: Wei and Gasse 1999). Integration of pollen with diatom and/or isotopic data from lacustrine sediment cores, in collaboration with Elise van Campo in e.g. Tibet and Madagascar (van Campo and Gasse 1993; Gasse and van Campo 1998) also led to important insights into past climate, including in some cases, changes in seasonality and wind directions (Gasse et al. 2011).

Some of my most memorable experiences came from Tibet, the "roof of the Earth" as Tibetans say, which plays a major role in Indian Monsoon circulation. I warmly thank Professor Paul Tapponnier (IPG-Paris, Singapore University), who invited me to participate in Franco-Chinese trips that focused primarily on neo-tectonics, but were also of tremendous interest for lake and paleoclimate studies (Fig. 4). Lacustrine sediments cores retrieved from lakes above 5,000 m a.s.l., during a multi-disciplinary survey in western Tibet (1989), provided the first continuous records from this poorly explored, highest and driest part of the Tibetan Plateau, which is presently outside the area of monsoon influence (Gasse et al. 1991). Results were interpreted as reflecting the orbitally induced westward migration of the Indian Monsoon front over the Tibet plateau (Wei and Gasse 1999). They also suggested that the African and Indian Monsoons acted almost in concert for at least the past 15,000 years (Gasse and van Campo 1994).

Involvement in PAGES and lake system modeling

I was involved in the PAGES program under the leadership of Professors J. Zimmermann and F. Oldfield, to develop the Pole-Equator-Pole transect through Europe and Africa (PEP3, 1991–2001). This sharpened my interest in inter-hemispheric teleconnections, ocean-land relationships, climate model reliability, and model-data comparison used to

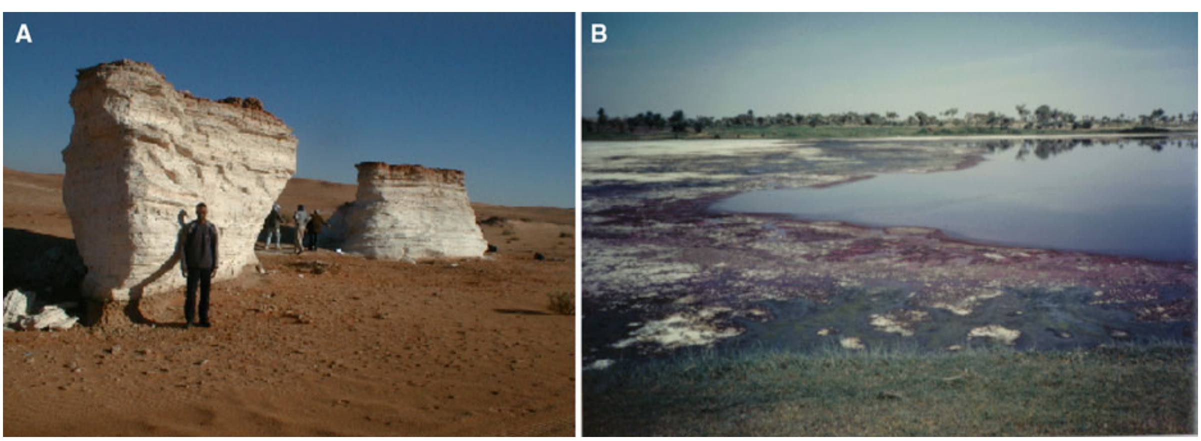

Fig. 3 Environmental diversity in the Sahara-Sahel. **a** Outcrops of early-middle Holocene lacustrine carbonates at Hassi el Mejnah, in the hyper-arid northern margin of the Western Great Erg, Northern Sahara. **b** Guidimouni, a sub-permanent waterbody in an inter-dunal depression from the Manga plateau, west of Lake Chad, Sahel. This waterbody is supplied by the local shallow aquifer. The *purple* mats are bacteria. The *white* patches are natron-trona precipitates. (Color figure online)

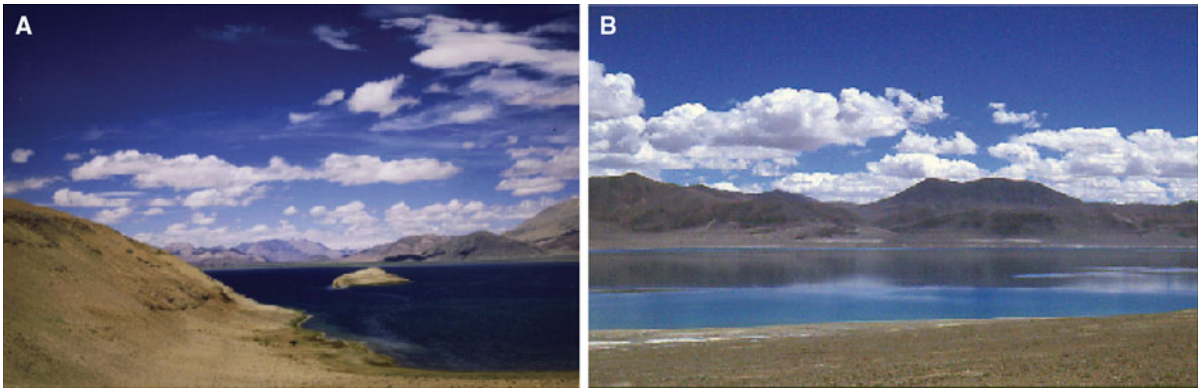

Fig. 4 Some lakes from western Tibet, the highest, driest part of the Tibetan Plateau. **a** Bangong Co (4,241 m a.s.l.), the largest lake of western Tibet, an oligohaline lake, just north of the Karakorum (Himalayan) escarpment. **b** Soda Lake Aksaishin (>5,000 m a.s.l.), just south of the Kunlun range

validate models (Gasse 2000). An important objective of the PEP3 project was to provide quantitative parameters and compare them to simulations derived from climate models. One way to translate paleolimnological data (lake level, salinity and isotopic composition) in terms of quantified controlling factors is by hydrological modeling of individual lakes. This approach helps elucidate lake functioning, can yield estimates of past conditions in a lake basin, and can be used to predict lake status under specific future scenarios. In many cases, this modeling step should be carried out prior to compiling existing or poorly filtered data at a continental scale for inferring past climate changes.

Lake system modeling became one of my important tasks in the 1990s. It was developed with PhD students, and once I moved to the CEREGE in 1998, with colleagues from this lab. Paleo-hydrology and paleo–vegetation proxies were integrated into energy and water balance equations to infer LGM precipitation and evaporation in the Tanganyika basin (Bergonzini et al. 1997). The respective roles of climate and human impacts on water level and salinity in Ethiopian Rift lakes during the past few decades were quantified by integration of a dynamic water- and chloride-balance model, with a catchment-scale hydrological model (Dagnachew Legesse et al. 2004). Study of a small tropical lake in southeastern Madagascar showed that fluctuations in the level of the shallow water table, here linked to sea-level changes, are crucial for the lake water and salt balance. It was also demonstrated that water vapour "recycled" from the lake surface contributed to the isotopic composition of atmospheric vapour (Vallet-Coulomb et al. 2006, 2008).

And now

I always enjoyed my job, with numerous comings and goings associated with fieldwork, lab analyses and data interpretation. To stop working is not easy—I remain fully involved in paleolakes studies, especially in a project that I initiated 8 years ago in Lebanon. There, I am happy to have led a young colleague from the CEREGE, Laurence Vidal, initially a paleoceanographer, towards paleolimnology. I am also happy to have attracted to the CEREGE young scientists involved in complementary methods for paleolimnology, e.g. Florence Sylvestre ($\delta^{18}O$ in diatom silica) and Christine Vallet-Coulomb (isotope hydrology and hydrological modeling). Today, I am proud that most of the 22 PhD students who I supervised or co-supervised have obtained permanent academic positions in their native or adopted countries (Morocco, Tunisia, Senegal, Ethiopia, Madagascar, China, Canada, USA, Australia and of course, France), and I appreciate having friends throughout the world. I confess, however, that my best "souvenirs" are and will remain the fantastic memories of travels to remote countries, seeing landscapes and colours that I could not have imagined and having the opportunities to interact with fascinating cultures and observe so many different ways of life.

References

Adamson DA, Gasse F, Street FA, Williams MAJ (1980) Late quaternary history of the Nile. Nature 287:50–55

Barker P, Fontes J-C, Gasse F, Druart J-C (1994) Experimental dissolution of diatom silica in concentrated salt solutions and implications for paleoenvironmental reconstruction. Limnol Oceanogr 39:99–110

Bergonzini L, Chalié F, Gasse F (1997) Paleoevaporation and paleoprecipitation in the Tanganyika basin at 18,000 years B.P. inferred from hydrologic and vegetation proxies. Quat Res 47:295–305

Dagnachew Legesse D, Vallet-Coulomb C, Gasse F (2004) Analysis of the hydrological response of a tropical terminal lake, Lake Abiyata (Main Ethiopian Rift Valley) to changes in climate and human activities. J Hydrol Processes 18:487–504

Fontes J-C, Mélières F, Gibert E, Qing Liu, Gasse F (1993) Stable isotope and radiocarbon balances of two Tibetan lakes (Sumxi co, Longmu co) from 13,000 BP. Quat Sci Rev 12:875–887

Fourtanier E, Gasse F (1988) Premiers jalons d'une biostratigraphie et évolution des diatomées lacustres d'Afrique. C R Acad Sci Paris 306:1401–1406

Gasse F (1977) Evolution of lake Abhé (Ethiopia and T.F.A.I.) from 70.000 B.P. Nature 2:42–45

Gasse F (2000) Hydrological changes in the African tropics since the Last Glacial maximum. Quat Sci Rev 19:189–211

Gasse F, Street FA (1978) Late Quaternary lake-level fluctuations and environments of the northern rift valley and Afar region (Ethiopia and Djibouti). Palaeogeogr Palaeoclim Palaeoecol 24:279–325

Gasse F, Tekaia F (1983) Transfer functions for estimating paleoecological conditions (pH) from East African diatoms. Hydrobiologia 103:85–90

Gasse F, Van Campo E (1994) Abrupt post-glacial climate events in West Asia and North Africa monsoon domains. Earth Plan Sci Lett 126:435–456

Gasse F, Van Campo E (1998) A 40,000-yr pollen and diatom record from Lake Tritrivakely, Madagascar, in the southern tropics. Quat Res 49:299–311

Gasse F, Talling JF, Kilham P (1983) Diatom assemblages in East Africa: classification, distribution and ecology. Rev Hydrobiol Trop 16:3–34

Gasse F, Téhet R, Durand A, Gibert E, Fontes J-C (1990) The arid-humid transition in the Sahara and the Sahel during the last deglaciation. Nature 346:141–146

Gasse F, Arnold M, Fontes J-C, Fort M, Gibert E, Huc A, Binyan L, Yuanfang L, Mélières F, van Campo E, Fubao W, Qingsong Z (1991) A 13000-year climate record from western Tibet. Nature 353:742–745

Gasse F, Juggins S, Ben Khelifa L (1995) Diatom-based transfer functions for inferring past hydrochemical characteristics of African lakes. Palaeogeogr Palaeoclim Palaeoecol 117:31–54

Gasse F, Vidal L, Develle A-L, Van Campo E (2011) Hydrological variability in the Northern Levant: a 250 ka multiproxy record from the Yammoûneh (Lebanon) sedimentary sequence. Clim Past 7:1261–1284

Rhodes TE, Gasse F, Ruifen L, Fontes J-C, Keqin Wei, Bertrand P, Gibert E, Mélières F, Tucholka P, Zhixiang W, Zhi-Yuan C (1996) A Late Pleistocene lacustrine record from Lake Manas, Zunggar (northern Xinjiang, Western China). Palaeogeogr Palaeoclim Palaeoecol 120:105–121

Vallet-Coulomb C, Gasse F, Ferry L, Robison L, van Campo E, Chalié F (2006) Hydrological modeling of tropical closed Lake Ihotry: sensitivity analysis and implications for paleohydrological reconstructions over the past 4000 years. J Hydrol 331:257–271

Vallet-Coulomb C, Gasse F, Sonzogni C (2008) Seasonal evolution of the isotopic composition of atmospheric water vapour above a tropical lake: deuterium excess and implication for water recycling. Geochim Cosmochim Acta 72:4661–4674

Van Campo E, Gasse F (1993) Pollen-and diatom-inferred climatic and hydrological changes Sumxi Co basin (Western Tibet) since 13,000 year BP. Quaternary Res 39:300–313

Wei K, Gasse F (1999) Oxygen isotopes in lacustrine carbonates of West China revisited: implications for post glacial changes in summer monsoon circulation. Quat Sci Rev 18:1315–1334

Williams MAJ, Williams FM, Gasse F, Curtis GH, Adamson DA (1979) Plio-Pleistocene environments at Gadeb prehistoric site, Ethiopia. Nature 282:29–33