doi:10.2533/chimia.2019.659 Chimia 73 (2019) 659 © Swiss Chemical Society

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Chemistry
Platform of the Swiss Academy of Sciences

The Jungfraujoch Research Station Designated as the Chemical Landmark 2019

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The Swiss Academy of Sciences has awarded the Jungfraujoch High Alpine Research Station the «Chemical Landmark 2019» as an important historical site of chemistry. SCNAT, SCG and the Swiss Crystallographic Society, together with partner organisations, acknowledged the scientific importance of the research station with a symposium in April at the University of Bern.

Silvio Decurtins, President of the International HFSJG Foundation and Member of the Board of SCNAT, and Christophe Copéret, President of the Platform Chemistry, unveil the commemorative plaque on the Jungfraujoch. (Photo: Heinz Kolb)

Cutting-edge Research Open to the World

Since its inauguration in 1931 by the International Foundation High-Alpine Research Stations Jungfraujoch and Gornergrat (HFSJG), the research station at 3450 meters above sea level has been open to scientists from all over the world. This cornerstone of Switzerland's reputation as host for international research stations was opened at a time when many European countries were sealing themselves off. The Jungfraujoch Research Station soon established itself as a station of global importance.

Many scientific breakthroughs started there and several Nobel laureates have researched at this station. For example, Patrick Blackett and Cecil Powell independently perfected the measurement of cosmic rays on the Jungfraujoch. This led to fundamental insights into the behaviour of elementary particles. The two Englishmen were both awarded the Nobel Prize for Physics (Blackett 1948 and Powell 1950) for their work based on these findings. Another success at the station was the precise determination of the Sun's radiation spectrum by the Belgian Marcel Migeotte. Since the 1950s, the station has been measuring the atmospheric concentrations of halogenated hydrocarbons using a method based on Migeotte's spectral analysis. These substances destroy the ozone layer in the stratosphere.

About 70 participants attended the «Chemical Landmark» symposium at the DCB of the University of Bern. (Photo: HFSJG)

Messages to Politicians

In his talk Prof. ***John Pyle*** from the University of Cambridge elaborated on the importance of such long-term measurement programmes. Continuous measurements are the only way to understand chemical processes in the atmosphere and to monitor emissions of pollutants. With data from the Jungfraujoch station it can, for example, clearly be shown, that the ban on halogenated hydrocarbons is largely complied with.

Dr. ***Lukas Emmenegger*** of Empa emphasised that such results are an important message to politics. They show that legislative measures such as the Montreal Protocol for the protection of the ozone layer are indeed effective. Emmenegger, who co-manages the National Air Pollution Monitoring Network (NABEL), presented another example: sulphur dioxide, which is harmful to humans and the environment. The measurement data from the Jungfraujoch[1] clearly show that pollution decreased sharply after Switzerland enacted the Ordinance on Air Pollution Control (OAPC) in 1986.

Inconsistencies can be uncovered with the help of gas measurements at the HFSJG infrastructures, as Emmenegger described using the refrigerant trifluoromethane (HFC-23) as an example. HFC-23 is a powerful greenhouse gas whose emissions must be reduced in accordance with the Kyoto Protocol. Empa researchers could show that emissions in Europe in 2008–2010 were significantly higher than those indicated in the reported statistics. By combining their measurement data with model calculations of atmospheric air movements and meteorological conditions, the scientists were able to localise the sources with pinpoint accuracy. For example, a chemical plant in northern Italy emitted 26 to 56 tonnes per year of HFC-23 during this period; while only 2.6 tonnes were recorded.[2] According to Emmenegger, this case also illustrates what can be obtained from combining environmental data with model calculations. For precise models, however, excellent data is needed. Today, around 100 gas species are measured on the Jungfraujoch.

Aerosols Influence the Climate

In addition to gas measurement, aerosol research plays a central role. Aerosols are particles dispersed in the air in the nanometer to micrometer range. As condensation nuclei, they play an important role in cloud formation and affect the climate system. To map these processes in the climate models, it is essential to understand them. The Jungfraujoch is an ideal place to study the physicochemical processes of aerosols in the lower free troposphere, explained Prof. ***Urs Baltensperger*** from the Paul Scherrer Institute (PSI). The research station records more than 20 aerosol parameters.

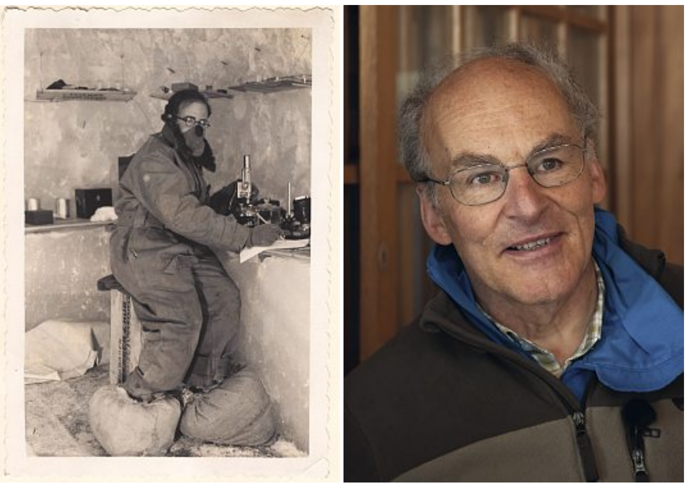
More than 50 percent of aerosol particles are formed in the atmosphere through the oxidation of molecules present there. For a long time it was assumed that the formation of such particles requires sulphuric acid and is anthropogenic, because sulphuric acid has only been emitted in relevant quantities since industrialisation. However, investigations by PSI and other research institutes on the Jungfraujoch could show, that naturally occurring substances also drive atmospheric aerosol production: *e.g.* pinenes, monoterpene hydrocarbons that evaporate from trees. Researchers at CERN could confirm this in independent experiments.[3]

Prof. ***Christian George*** of the University of Lyon explained how fine dust and the aerosols arising from it impair the formation of ozone in the stratosphere. Climate change and increasing desertification are intensifying these processes.

Visionary, Adventurer, Pioneer

The 1962 Nobel Prize in chemistry for deciphering the molecular structure of the blood pigment haemoglobin also leads to the Jungfraujoch. It was there, that Max Perutz, a researcher from Cambridge, England, studied the structure of ice and glaciers in the 1930/40s. His interest in finding correlations between structure and function later led him to the study of complex biomolecules and so to his Nobel Prize. As a passionate mountaineer, the native Austrian enjoyed working in the high Alps. This passion also paid off in other ways: the Ski Club of Great Britain and the Alpine Ski Club financially supported his research expeditions.

His son, Prof. ***Robin Perutz***, also a chemist and a professor at the University of York, scrutinized the insights his father had gained at the Jungfraujoch. He could confirm that the results about the crystal structure and the flow mechanisms of glaciers are still valid. As early as 1950, Max Perutz recognized, that due to the flow mechanism,[4] glacier length is an excellent indicator for climate change. Perutz junior also entertained the audience with anecdotes from Max Perutz's adventurous life as a researcher: from losing the most expensive equipment of the research plan from the luggage rack through a train window, to broken legs of his assistants while learning to ski to experiments on the glacier during lightning strikes and storms, to internment and subsequent express naturalization in England during the Second World War, or – *nomen est omen* – participation in the British military's top secret 'Habakkuk' project to construct an aircraft carrier from Pykrete (a composite of ice and sawdust).



Max Perutz using a polarized microscope in the ice laboratory on the Jungfraujoch (around 1950) and Robin Perutz on his first visit to the research station on the occasion of the award of the «Chemical Landmark 2019» (Photos: Gerald Seligman, Heinz Kolb)

Prof. ***Sine Larsen*** of the University of Copenhagen, winner of the Max Perutz Prize 2018 for outstanding achievements in crystallography, paid tribute to Max Perutz for his pioneering work in the field. Perutz demonstrated that crystallographic structure elucidation by X-ray diffraction can also be applied to large proteins. Larsen showed how much the methods have evolved since then. In addition to computers, the biotechnological production of proteins (recombinant proteins), the use of synchrotron radiation and free-electron lasers or cryotechnology for cooling crystals to very low temperatures have brought enormous progress. Since the mid-1990s, the number of identified protein structures has increased exponentially.

Prof. ***Stefan Klotz*** from Sorbonne University impressively explained how ice can assume different crystalline structures depending on pressure and temperature. Today there are about 20 different types of ice known.

Focus on the Environment and Climate

Not only the financing opportunities, but also the research priorities on the Jungfraujoch have changed over time. Initially, the focus was on meteorology, altitude medicine, astronomy and radiation research, said Prof. ***Markus Leuenberger***, director of the High-Alpine Research Stations Jungfraujoch and Gornergrat (HFSJG). Today, the focus shifted to interdisciplinary environmental and climate research, in particular physicochemical analysis. The scientists are particularly interested in the state of the atmosphere and how changes affect it. Most of the measurement data reaches the workplaces in the valley directly *via* the Internet.

Unchanged remains the international orientation of the station: Among others, the station is part of the Global Atmosphere Watch network and acts as a key station in various national, European and global networks. Around 50 projects are currently running on the Jungfraujoch, many of which are headed by Swiss research institutions.

The SCNAT «Platform Chemistry» would like to thank the Swiss Chemical Society, the Swiss Crystallographic Society, the International Foundation for High-Alpine Research Stations Jungfraujoch and Gornergrat, the Department of Chemistry and Biochemistry of the University of Bern, Jungfrau Railways, Anton Paar GmbH and Merck KGaA for organizing and supporting the symposium and the inauguration ceremony.

Received: June 19, 2019

[1] *https://www.bafu.admin.ch/dam/bafu/de/dokumente/luft/externe-studien-berichte/so2-immissionen_schweiz19802010.pdf.download.pdf/so2-immissionen_schweiz19802010.pdf*

[2] C. A. Keller, D. Brunner, S. Henne, M. K. Vollmer, S. O'Doherty, S. Reimann, *Geophys. Res. Lett.* **2011**, *38*, L15808, doi:10.1029/2011GL047976.

[3] J. Kirkby *et al., Nature* **2016**, *533*, 521, doi: 10.1038/nature17953; J. Tröstl *et al., Nature* **2016**, *533*, 527, doi: 10.1038/nature18271; F. Bianchi *et al., Science* **2016**, *352*, 1109, doi: 10.1126/science.aad5456.

[4] The flow is proportional to a higher order of the sheer stress, which means that if the glacier's thickness is increased by 10%, the flow approximately doubles. See M. F. Perutz; *The Listener* 6 Apr. **1950**, 601-2; *http://tinyurl.galegroup.com/tinyurl/9uAGm9*.

SCS Symposium 'On the top'
The symposium at the Department of Chemistry and Biochemistry of the University of Bern acknowledged the international importance of the Jungfraujoch High Alpine Research Station (HFSJG).

Urs Baltensperger, Paul Scherrer Institute and ETH Zurich
The Jungfraujoch: An ideal site to study aerosol processes in the lower free troposphere
In order to develop reliable climate models, it is necessary to understand the aerosol processes in the atmosphere. Among other things, they influence the formation of clouds.

Lukas Emmenegger, Empa
Top-down emission estimation – measurements and modelling at Jungfraujoch
Mathematical models can be used to identify the atmospheric transport of air pollutants and their sources. However, this requires good measurement data.

John Pyle, University of Cambridge
Understanding atmospheric composition: a modelling and observation problem
High-quality long-term data are the basis for reliable monitoring of air pollutants and greenhouse gases. The combination with model calculations makes it possible to check the effectiveness of regulatory provisions.

Christian George, University of Lyon
Particles are in the air: from molecules to global change
Fine dust and the resulting aerosols impair the formation of ozone in the stratosphere. Climate change and increasing desertification are intensifying these processes.

Stefan Klotz, Sorbonne University
Ice: at low and high pressure
Depending on pressure and temperature, ice takes on a different crystalline structure. Today there are about 20 known types of ice.

Sine Larsen, University of Copenhagen
Protein crystallography from hemoglobin to free electron lasers
Max Perutz was a pioneer in the field of crystallography. Since then, the methods for structure elucidation have developed remarkably.

Robin Perutz, University of York
The Jungfraujoch and Max Perutz: expeditions that shaped understanding of glaciers
Max Perutz's work on the crystal structures of glacial ice and the flow behaviour of glaciers is still valid today. He also drew attention early on to the disappearance of glaciers as a result of rising temperatures.