SUN Liguang: Smell Climate Changes in Penguin Droppings

By XIN Ling (Staff Reporter)

On the frigid land of Antarctica, a man in a blue jacket and black rain boots was tottering against the howling winds and whirling snow. He was almost blinded by the snowflakes but apparently looking for something, leaving behind him a long trail of footprints. Suddenly, his eyes opened wide and his face was glowing with excitement – a muddy lake near penguin rookeries, something he had been seeking after for months! He jumped and shouted like a child.

The man was SUN Liguang, a professor of geology from the University of Science and Technology of China (USTC), who traveled to the South Pole for the first time in his life. That day, he collected four columns of muddy sediments, smelly of penguin droppings, from the lake, trekked a new path for decoding climate changes, and started an amazing scientific journey.

The penguin dropping collector

On a spring day of 1998, the uneventful life of SUN Liguang, a 53-year-old professor of geochemistry at USTC, was interrupted by a phone call from one of his former students, inviting him to participate in the application for China’s 15th scientific expedition to the South Pole.

“I had never dreamed of travelling to the South Pole. After over two decades of teaching and research, it could be an ideal chance for me to collect new inspirations,” the professor was still excited when he recalled the phone call.

Prof. SUN Liguang on the Fildes Peninsula in December, 1998.
The application was finally approved, and then Prof. SUN began to feel the pressure: how could he find “something new” to study in the South Pole after so many discoveries had already been made about the glaciers, lakes and earth there? As an ordinary university professor, SUN hardly had any scientific grants or equipment to afford a complicated mission.

The question lingered on his mind for several days until an idea suddenly stroke him: penguin droppings! The only materials that had not been studied before.

“Although some friends and colleagues doubted my plan, I was quite confident because as a major animal species in the Antarctica, penguins come from the ocean, eat krill, poo on land, and their droppings are then washed into the lakes. Based on this ecological circle, we can analyze penguin droppings or the impacted sediments to study their population and the controlling factors such as climate change and human activity,” explained Prof. SUN.

With a ready heart and good confidence Prof. SUN arrived in the Antarctica on December 13, 1998. As soon as he and his teammate embarked on Ardley Island, they set out to look for penguin droppings. To their great disappointment, there were hardly any in the penguin rookeries; the pink penguin droppings were swept away by rain, snow or wind into the ocean soon after they were excreted.

Without penguin droppings, Prof. SUN’s plan would definitely be a failure. They kept searching in the following three months, but the best they could find were sediments up to a dozen centimeter deep, representing a maximum time span of 50 years, way short of the planned 200 years.

Just at the moment they were about to give up, Prof. SUN and his teammate finally caught light at the end of the tunnel. Only four days before their due departure, they found, by chance, a muddy and smelly lake next to a penguin rookery. This lake very likely contained the aged penguin droppings they had been seeking after for so long, and Prof. SUN was very excited. With the help of other colleagues, he dug four sediment cores from the lake.

At Prof. SUN’s lab at USTC, one 67.5cm-long sediment core was divided at one-centimeter interval, dried in the air, and analyzed for their chemical composition. Accurate carbon-14 dating showed that the core was about 3,000 years old. The concentrations of nine “bio-elements” – strontium, fluorine, sulfur, phosphorus, selenium, barium, calcium, cuprum, and zinc – in the core varied synchronously with sediment depth.

“When I was trekking on the snow-covered mountains of the South Pole, I realized that it might be easier to walk in other people’s footprints, but you’ll lose the chance to leave your own marks.”

– SUN Liguang

“To me, these concentration curves look like a graceful group dance. I’ll always remember the moment I saw them, the best minute in my life enlightened by the beauty of science,” Prof. SUN smiled.

The extremely high concentration of fluorine – a characteristic of krill, penguin’s main food – and the relative abundance of phosphorus confirmed that the samples were mainly made up of penguin droppings.

Since the element concentrations were positively and significantly correlated to the amount of penguin droppings in the sediment core, they provided a reliable proxy of penguin population and thus climate over the years. Data showed that penguin population had four major fluctuations in the past 3,000 years. It peaked somewhere between 1,400 and 1,800 years ago and dropped dramatically about 1,800 to 2,300 years ago, indicating that a moderate temperature was favorable for the existence and reproduction of penguins.

In 2000, the article “A 3,000-year record of penguin populations” co-authored by Prof. SUN and his colleagues was published by Nature. It was the first Nature paper from Mainland China in the field of South Polar studies.

Dr. WANG Yuhong, a collaborator and old friend of Prof. SUN who works at the National Institute of Health of the United States, appreciated the scientific significance
of SUN’s work. According to Dr. WANG, climate research is vital for Earth and our civilization’s prosperity and survival, and remains at its embryonic stage. Unlike other physical sciences, climate science does not have the luxury of testing models and theories in well-controlled labs. To a large degree, the expansive atmosphere and the gigantic ocean are the labs, and climate science has to depend upon long and continuous “historical observations” to test and improve its theories and models. Before time machine is a reality, climate science has to use various proxy materials such as tree rings and ice cores and reconstruct the historical events. Previous proxy materials are good for either very small (100 years or less) and very large (100,000 years or longer) time scales; they are less effective for medium time scales (100-100,000 years). “Climate history of medium time scale, however, is the most relevant to our current climate, and the effective time scale of the smelly penguin droppings sits right in the middle,” Dr. Wang said.

From South Pole to South China Sea

The Antarctic expedition opened a door to Prof. SUN and turned over a new page in his scientific career. Based on his findings in the South Pole, Prof. SUN developed a systematic methodology to reconstruct climate history from animal-impacted sediments.

For instance, by studying a century-old sediment core containing seal hairs from the South Pole, Prof. SUN and his students discovered that the population of krill – seal’s favorite food breeding in cold water near sea ice – has been decreasing along the West Antarctic Peninsula. They attributed this to the climate warming and the retreat of sea ice in the area in the past 100 years or so.

Besides the South Pole, Prof. SUN conducted investigations in the North Pole and Xisha Islands, South China Sea, where he has opened a new frontier in his scientific endeavor.

“If I have to choose between the South Pole and the “human world” to spend the rest of my life, I’ll take the latter without hesitation: I confess. But I shall also confess that the South Pole will be a forever shelter of soul and spirit for me to remember, dream, and pursue. Maybe I cannot run away from the chaos of the “human world” to live a transcendent life. However, amid the chaos, I will taste the tranquility of the Antarctica and hear the harmonious and affectionate echo coming from the kingdom of ice and snow. The echo will reach me more and more clearly and blend with this world in the end. – From SUN Liguang’s A Hundred Days in the South Pole”
“The South China Sea is a transition zone between China and the tropical regions, and the reconstruction of ancient climate in this area is an important and challenging task,” Prof. Sun pointed out.

In 2003 and 2008, his group collected sediments from eight untraveled islands in South China Sea. “These sediment cores contained mainly bird droppings and coral sands deposited with time. Generally speaking, a light-colored segment of a core with relatively big sand grains was formed during rainy years, while a dark segment with smaller sands was formed in years with less rainfall,” explained Mr. YAN Hong, a doctoral candidate of Prof. SUN.

From these sediment cores they obtained a large amount of proxy data about the climate in Xisha Islands more than 1,000 years ago. As their analyses went deeper, they discovered that the studied region received more rainfall in the cold period (AD 1400-1850) than that in warmer periods, an observation contradicting established climate models. Previously, the precipitation in west Pacific Ocean is believed to be mainly controlled by Intertropical Convergence Zone. The contradiction provided a piece of new and strong evidence that a widely known climate phenomenon called “Pacific Walker Circulation” plays a substantial role in the precipitation.

El Niño is one of the most important climate events on the Earth. It not only directly affects the climate in the west Pacific Ocean and East Asia, but also impacts regions far north in the Northern Hemisphere. Based upon modern statistics, Prof. SUN’s group proposed an ingenious idea: using precipitation data as the time machine to see what happened in the past. His group was able to extend the El Niño history from previous about 800 years to over 2,000 years, and they observed striking links between El Niño and solar irradiance and the average temperature of the Northern Hemisphere.

Their findings were published in world-leading scientific journals and widely reported in the media. “Our study about the Pacific Walker Circulation and El Niño will hopefully help reconstruct the history of how these climate phenomena impacted our ancestors and make mid and long-term climate prediction in China,” said Prof. SUN.

An open-minded teacher

In Mr. YAN’s eye, Prof. SUN is not only a successful scientist but also a unique and amazing teacher.

“He’s definitely one of the most liked teachers in our university,” Mr. YAN remarked. Famous for his broad knowledge, humor and eloquence in class, Prof. SUN has more than 1,000 undergraduate applicants for his geochemistry course every year. “He encourages original thinking, and urges us to ask scientific questions on our own. In fact, he himself is a constant doubter of traditional theories.”

Besides Mr. YAN, Prof. SUN has trained more than a dozen doctoral students. Many of them have grown into outstanding scientists, and are working as independent researchers. For instance, Prof. XIE Zhouqing, a former student of SUN, is an expert in persistent organic pollutants and now the director of the Institute of Polar Environment at USTC.

With Prof. SUN’s efforts, the Institute of Polar Environment has become a major research unit at USTC and a leading laboratory in the field of polar studies in China. Its research has been supported by the National Natural Science Foundation of China, the State Oceanic Administration, the National Basic Research Program of China, as well as CAS and USTC. By far, a total of 32 scientists and students in Prof. SUN’s group have participated in China’s scientific expeditions to the South Pole. Prof. SUN might have never imaged this when he was preparing lessons in his shabby office in the 1990s.

A “late bloomer” is the name given to Prof. SUN by his friend and colleague Dr. QIN Dahe, a glaciologist. Thirteen years ago, he travelled to the South Pole for the first time in his life and smelled historical climate changes in penguin droppings. Now, after a fruitful decade and in his sixties, he will continue to “bloom” and bring new surprises to polar and climate change sciences in China and the world.

“For my group, it is just the beginning of exploring some of the most important mechanisms of climate change on Earth”, Prof. SUN’s smile was as warm as the sunshine in his office on a sunny winter day in Hefei.