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Progress of Glaciology and Geocryology Incubation Program of the National Natural Science Foundation of China

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The 10th 5-year Plan for National Natural Science Foundation of China (NSFC) for fostering competent research teams and highly qualified scholars in fundamental research in glaciology and geocryology was based on the strategy of incubating "competitive, problem-solving oriented and motivated fledgling scientists, who can effectively lead and greatly advance the aimed subjects and conduct the cutting edge research". This principle has been playing crucial roles in restructuring the team aiming at world-first-class research projects and at solving critical problems in national key projects. It was under the guidance of this strategy that the key research team for mitigating the challenging and differential frost and thaw hazards along the Qinghai-Tibet Railway (QTR) had been formed, that a strong group focused on the cryosphere (snow, ice and permafrost) research was re-established and enhanced. These accomplishments have facilitated the formation and growth of highly motivated competitive research teams on comprehensive and integrated fundamental research, which promoted, intensified, and expanded the research programs in glaciology and geocryology.

Key words glaciology, geocryology, research projects/programs, incubation and motivation, achievements

1 Restructuring research teams during the critical period of the 10th 5-year plan

The implementation of the Glaciology and Geocryology Incubation Program (GGIP) during the 9th 5-year Plan (NFYP) had the goal of retaining the experienced and accomplished researchers, training young teams, attracting outstanding scientists and promoting the growth of young glaciologists and geocryologists. Effective distance learning systems, and regular seminars and workshops on the latest developments of cryospheric research and frozen ground engineering provided extensive outreaches for the glaciology and geocryology program. The visionary strategy of the NSFC timely alleviated of the shortage of well-disciplined and highly qualified scientists, incubated and refined competitive teams for the GGIP and national development programs.

The development of scientific research depends on a number of factors, and the key factor is well-qualified research faculty that can compete on the cutting edge and meet the national needs for basic research and socio-economic development. At the beginning of the Tenth Five-year Plan (TFYP) Period, it was already clear that the development of the GGIP was no longer just a purely scientific research program; it was also closely related to the construction, the ecology, the hydrology, and the economic development of the cold regions of China. The GGIP studies should not be limited to glaciology and geocryology; they should take into account the climatic, engineering, ecological, hydrological, and economic aspects. Only the multidisciplinary, comprehensive and integrated research could provide the solutions for the challenging cold regions problems under rapidly and significantly changing climates. Therefore, it was deemed necessary to restructure the research teams of the glaciology and geocryology program, which included the following four aspects, in the TFYP.

First, on the basis of relatively stabilizing basic research personnel and projects, upgrading the quality of the scientific researchers and their projects should be prioritized for producing the academic leaderships

and first class results in science. Second, with the research projects undertaken during the TFYP, the country needed research faculty with the capabilities for interdisciplinary research, innovative solutions and effective project management. Third, with the change of investigative concepts and the formation of the "theory-data (inspection, observation, testing, experiment, and analysis)" spiraling elevations of a new, creative thinking, it was necessary for technicians to provide the support in methodology and techniques for the implementation of integrated studies. Finally, glaciology and geocryology are highly specialized disciplines; few people know them and much less people understand them. The development of glaciology and geocryology need extensive support which can only be obtained from increased social awareness on these subjects. Therefore, it needed effective spreading of scientific knowledge, methods and social awareness of the relationships between the cryospheric environment and human society to inspire next-generation scientists and reporters to engage in the research on glaciology and geocryology.

2 Measures to facilitate competitive research staff training and programs

Pilot projects with limited but substantial funding were established to support promising visionary research projects, to meet urgent needs and to support fledgling junior scientists, who still lacked other funding sources. These funds supported methanogen diversity research on the Qinghai-Tibet Plateau (QTP), CO_2 exchange between different ecosystems and the atmosphere in the Qilian Mountains, and inversion of hydrological data and hydrologic modeling for cold regions with very limited, or without, observational data. Two research groups were established. The first group of six members, headed by Dr FJ Niu and Dr. HY Feng, was established to study microorganisms in permafrost environments. The second group of four members, headed by Dr. YH Gao and Dr. GM Jiao, was established to inverse hydrological and climatic data. A permafrost engineering simulation group, mainly composed of Professor YM Lai, Dr. XF Zhang and Dr. WB Yu, was created for the study of finite element analysis, which provided the solid support for the application and approval of establishing the master's and doctorate degrees in cold regions geotechnical engineering at CAREERI. The pilot projects also supported the remote sensing and GIS research on snow and ice, headed by Professors X Li and J Wang, who also established the master and doctorate degrees education base in cartography and GIS. A pilot project was established for regaining the competitive edges of CAREERI/LIGG on the physics of snow and glaciers. Professor DN Xiao was introduced for developing cold regions ecology, leading to the authorization for hosting master's and doctorate degrees in ecology.

The construction of the QTR provided a pilot project in team building and personnel training by project, which is important in the development of human resources, and leadership, and strengthening the quality of research for the TFYP. The GGIP-supported research team adopted the latest project and knowledge management and supported the QTR permafrost research project. Young scientists were cultivated and motivated in these processes to lead in both research teams and disciplines. The teams for the QTR project were developed to be learning team managers. The support during the NFYP trained Professors W Ma and QB Wu as leading scientists in the QTR permafrost engineering research programs. Their core team won the Major Innovation Contribution Prize of the Chinese Academy of Sciences (CAS) in 2001 and 2002. They also claimed the "Outstanding Team" Award of the CAS and State Department of Human Resources. "The Outstanding Team for Building Innovation Culture" was awarded to the SKLFSE by the CAS in 2002.

The new strategy for development of qualified scientists has led to a new research environment for both the leading scientists and research team members. This has resulted in the establishment of new, promising leaders in emerging subjects, extended research in glaciology and geocryology, and enhanced the multi-disciplinary integration. It also brought new thoughts to solve the key issues of the QTR permafrost problems and the water resources management issues in the Hei'he River Watershed.

3 Establishing academic environments productive for highly qualified and motivated scientists and research teams

Several platforms were established to benefit more researchers by sharing information and experiences. The pilot projects for talent incubation sup-

ported researchers, such as Professor YN Zhang, Dr. WZ Wei and Dr. ZH Zhang working on establishing and improving high-performance network and computing environments, introducing and integrating forms of software such as ANSYS, ADINA, FLUENT, SME, CCM3, MMS, VIC, and SSIB to quench the computing needs in studies of glaciers, frozen ground, climate, spatial modeling, cold regions ecology and hydrology. The funds also engendered the professional growth of multi-disciplinary personnel in the "Integrated Experiment of the Hei' he River Watershed" project. A research team, headed by Academician GD Cheng and joined by Professors X Li, ES Kang, ZM Xu and YN Zhang as the key members, conducted preliminary hydrological and ecological modeling and inversion studies of alpine radiation and precipitation on mountain areas with very sparse observational data. All this work has preliminarily paved the way for integration research. The platforms have benefited more than 100 scientists, and promoted staff training and education through projects such as QTR, the Hei' he River Watershed System, as well as relationships between glaciers and climate, permafrost and climate, snow and climate, river system ecology, watershed and eco-hydrological processes. At present, the project of "Integrated study of the Hei' he watershed" led by Professors X Li and ZM Xu focuses on the relationships between river system ecology and hydrological processes, which has become the new innovation point of cold regions research.

4 Progressive development of solid foundations for cryospheric research

We first concentrated on providing the well-disciplined and qualified researchers needed by the country, and then developed the relevant subject matter. During the TFYP, the training was specially paid to developing the research capabilities of young scientists and PhD students. These projects concentrated on general and integrated permafrost research; the latter part concentrated on resuming snow and ice research projects. A research group, headed by Academician GD Cheng, supported by Professors W Ma and QB Wu as leading scientists was established, and joined by 12 PhD/master's students as key team members. Proactive cooling techniques were proposed to ensure the structural safety and long-term stability of the QTR embankment using the protecting permafrost principle, and changed the design concept from a static to a dynamic mode to accommodate the change of designs. The long-term stability of engineering infrastructures was evaluated through the assessment of the stability of permafrost foundations. Many experimental engineering measures, such as air-duct ventilated roadbed, crushed rock revetments, shading boards (awnings) on the slopes, thermosyphons, and insulation were investigated. These experimental studies provided the theoretical and practical data for the QTR design and construction. All this research made critical contributions to the change from "Stipulations governing the design and construction of the Qinghai-Tibet Railway permafrost engineering". The junior leading scientists incubated through the GGIP played a critical role on the QTR permafrost engineering research project, which in turn greatly advanced the geocryology and permafrost engineering. Due to their great contributions to the QTR projects, they received many awards. For example, the "Demonstration project for construction technique in permafrost regions along the Qinghai-Tibet Railway" won the "Outstanding Science and Technology Achievement Award" of CAS in 2005. The project "Forecast and key techniques for the comprehensive mitigation of frost hazards along the cold regions highways and tunnels" won the Second-class National Science and Technology Advancement Award in 2005. The "Forecast and comprehensive mitigative techniques for frost hazards associated with tunneling in permafrost on the Qinghai-Tibet Plateau" won the Gansu Provincial Science and Technology Progress Prize in 2003. The "Research on the permafrost environments and long-term subgrade stability of the Qinghai-Tibet Highway" received the Gansu Provincial Science and Technology Achievement Award (Second Class) in 2003.

GGIP Personnel incubation projects, such as the "Response of glaciers to climatic change and their impacts on water resources"; the "Methodology and stipulations for observing glaciers and their changes"; "Interactions between snow hydrological processes and climatic change"; "The snow hydrology process"; and "Spatio-temporal variations of stable isotopes of snow cover in a typical warm glacier region strongly impacted by monsoon climates" have made significant contributions to advancing cryospheric sciences in China. As a result, Professors NL Wang,

SY Liu, and ZQ Li and five junior scientists established a core team on general glaciology; Professors YQ He, J Wang and YH Gao and 6 junior scientists formed a team on snow research. These projects and the resultant two research teams rescued the endangered basic snow and ice research. As a result, the research on general glaciology, glacial micro-climatology, snow physics and chemistry of snow, the physics of glaciers, and the relationships between snow and ice covers and climate systems have been promoted and flourished.

5 Balanced and sustainable development of glaciology and geocryology in the future

The National Basic Scientific Talents Funds (NBSTFs) have been a powerful impetus to advance glaciology and geocryology, to assist a group of promising junior scientists in establishing creative and innovative teams for conducting cutting edge research in glaciology and geocryology, and for solving challenging environmental and engineering problems for socio-economical development of western and northeastern China. During the 9th 5-year Plan, the focus of the GGIP was on "*Retaining existing staff, attracting qualified competitive scholars from outside, and incubating fledgling scientists*", with many visible results in advancing glaciology and geocryology in China. During the 10th 5-year Plan, the GGIP adopted a strategy of "*Providing a favorable academic environment for leading scientists, and motivating leading scientists to advance the aimed subjects*", which extensively upgraded the quality of scientists and their research. The NBSTFs promoted, deepened and extended the magnitude and scale of the subjects of glaciology and geocryology, and facilitated inter-disciplinary team development. These are reflected in the following concrete visible results: inter-disciplinary and integrated research on water resources engineering management at the watershed levels, integrated simulation and modeling using the latest geotechnology, and the decision support systems in watershed economy, hydrology, ecology and managerial sciences. These results were well received in the fields of the related subjects and were considered visionary, creative and innovative. As a result, many junior scientists became leading scientists: Professors W Ma and QB Wu led in the QTR permafrost engineering research; Professor YM Lai received the support of the NSFC for Distinguished Young Scholars; two doctoral graduates received the "100 Excellent Thesis of China" award; and, three of graduate students were awarded the CAS President Award for Excellence.

However, the incubation and education of glaciologists and geocryologists are still facing many challenging problems after the Ninth and Tenth Five-year Plans. At present, the talents for frozen ground engineering are comparatively better developed than before the GGIP; however, they still lag behind difference with cold regions scientists and engineers in developed nations. The QTR engineering projects attracted many geocryologists, weakening the basic research on permafrost, which might adversely affect the long-term development of geocryology in China. From the perspectives of climatic and environmental changes and the eco-environments, permafrost is critically important to the global climate systems and ecology. In this respect, general geocryologists still need to be fostered with cutting edge projects. Similarly, as the most important components of the cryosphere and many other spheres, snow and glaciers can have significant influence on climate change, water resources, and subsequently greatly impact the sustainable socio-economic development of China. Because of the focus on ice core research and some other national scientific planning reasons, the basic and applied research on glaciers and snow and snow and glacier hazards, almost became extinct. Many researchers either left or changed their research directions. Therefore, it is still urgently needed to increase the support, cultivate the promising core staff and upgrade their academic qualifications and professionalism, and foster the cooperative research groups, in order to meet the requirements of cryospheric research.

In summary, it is necessary to provide relatively stable funding to support the incubation and education of glaciologists and geocryologists, and persistently sustain and rapidly improve the cutting edge quality of the research on glaciology and geocryology. During these past years, great progress has taken place and the quality of research teams has improved. However, a stable flow of highly qualified and devoted scientists are still in the incubating periods. Moreover, staff education should envision the project needs in the future. Therefore, it is certain that the stable support from the NBSTFs is critical for the sustainable development of glaciology and geocryology in China.