

This is the seventh article of a 15-part series on the GLOF research and mitigation project between May 2009 and March 2012. The articles will highlight latest findings on glacier, glacial lakes condition and natural hazards in the Bhutan Himalayas. Experts from the department of geology and mines (DGM), Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST) are involved with the project. This article looks at the glaciers of Soe and Chamkhar Chu.

Bhutan's glacial history

What was past glaciation in the Bhutan Himalayas like? Current mountain landscapes (i.e. glacier lakes, ancient lakes, water fall, and rock cliff etc.) relate largely to the past behaviour of Bhutan's glaciers. Although it is reported that Bhutan's mountain glaciers have shrunk in recent years, past behaviour of Bhutan's glaciers has not been well studied, which also limits the understanding of glacier-related hazards. An understanding of glacial history is necessary to understand present conditions and to predict future trends.

The collective understanding of climate change over the last 100,000 years is largely based on analyses of sediment cores from the Atlantic sea floor and ice cores from the Antarctic and Greenland. For example, these analyses show that for the last 80,000 years, glacial and interglacial cycles have alternated at intervals of about ten thousand years on average (i.e., repetition of cold and warm period). We live in interglacial period. The present interglacial period, representing the last ten thousand years including today, is called the "Holocene". During the Last Glacial period (between c.a.70,000 and 10,000 years ago), Scandinavia and North America were covered with continental ice sheets of over several thousand meters in thickness, and average annual temperatures in the northern Hemisphere were 6-7°C lower than at present. Mountain glaciers in the world also expanded largely in the Last Glacial period, compared to the present.

Glacier land forms are evidence of past glacier expansion. Typical land forms associated with glaciers in mountainous areas are moraines, U-shaped valleys, and cirques. (1) Moraines consist of soil and rock transported

and deposited at the margins of advancing glaciers. The spatial distribution of old moraines indicates the past positions of glacier fronts. The distribution of glaciers at periods in the past can be depicted on moraine distribution maps and the timing of advances dated using a variety of methods, such as radiocarbon dating. (2) U-shaped valleys are troughs topography eroded by glacier advance, and have steep straight sides, and flat bottoms, as the "U" letter.

Yak herders use these open grass land for yak grazing. (3) Cirques are amphitheater-like valley heads formed at the upstream ends of valley glaciers as a result of glacier erosion. Topographical traces of past glacial expansion are evident in the Bhutan Himalayas, and can be found on the "snowman trek" from Paro to Nikka Chu, which was hiked by the authors in 1998. The variety of present land forms include large topographic features that developed in the Last Glacial interval, and subtle Holocene features associated with minor climate change. In Holocene, glaciers repeatedly advanced and retreated within the short range as climate varied between moderate warm and cold, and these changes are also recorded in the development of glacial land forms.

Lingshi Dzong, in the northwestern region of Bhutan, was constructed at

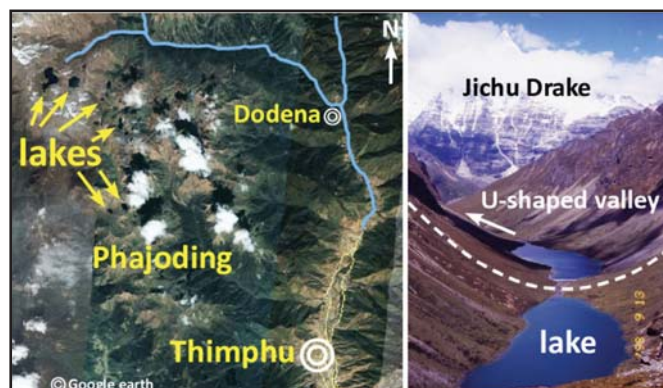


Figure 2. Clear blue lakes on the U-shaped valley, upstream from Thimphu (left) and Paro (right)

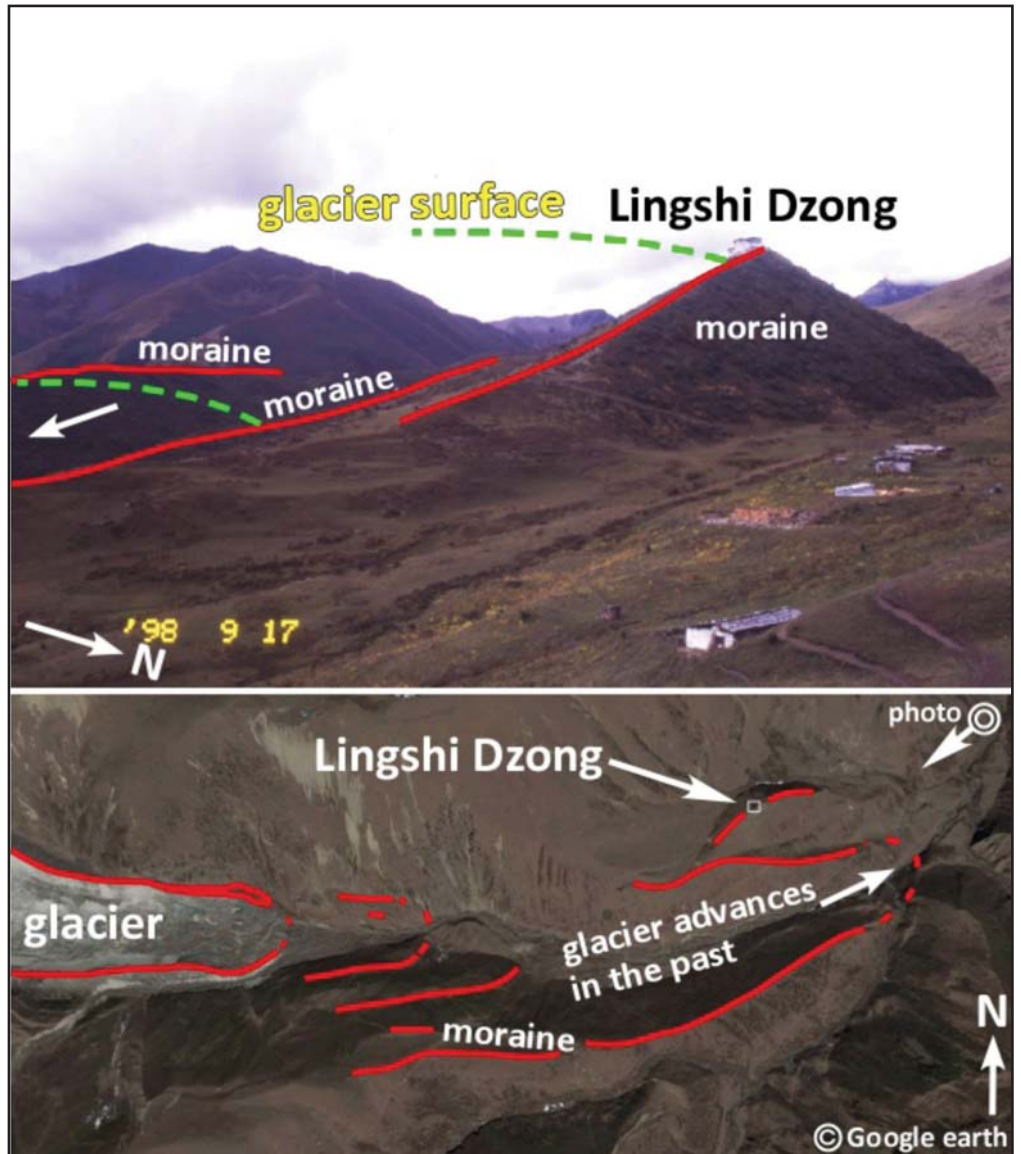


Figure 1. Lingshi Dzong, on a moraine formed

the top of the old moraine ridge that formed during the Last Glacial period (Fig. 1). Pg.21

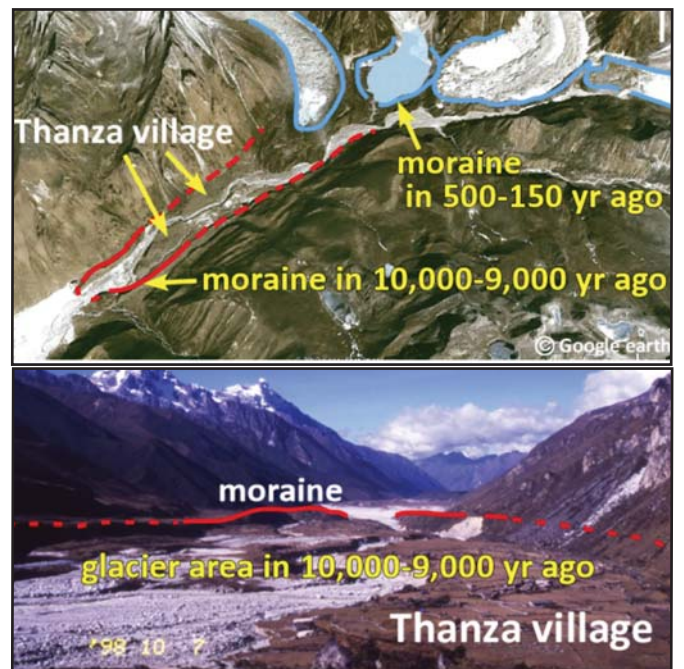


Figure 3. Glacier coverage in the Lunana region between 10,000 and 9,000 years ago. Yellow line shows the margin of the glacier ice area

Bhutan's glacial history

From pg.20

This moraine is now 4-5 km downstream from the current glacier terminus. The topographic height of Lingshi Dzong indicates the position of the glacier surface during its most expansion. This may conjure up images of glacier thickness and scale in the past. Many clear blue lakes (a 500 m-long) upstream of Thimphu and Paro are located near mountain ridge (Fig. 2). These lakes are located where stream water accumulates in a low part (depression) of the U-shaped valley formed by past glacial advance, and where the valley is dammed by an old moraine. Clear blue ancient alpine lakes are religious objects for Bhutanese people. These are ancient lakes rather than glacier lakes that developed after the most recent glacier shrinkage due to recent atmospheric warming.

The village of Thanza in the Lunana region is surrounded by moraines that formed during glacier expansion between ten and nine thousand years ago (Fig. 3). This means that the present village site was completely covered by glacier ice at that period. In 1998 field research, we could reveal the background of appearance of Raphsthreng Glacier Lake in Lunana. We found that moraine dam body was formed by different advance events of Raphsthreng Glacier in ~2,000, ~1700, and 500-150 years ago (Fig. 4); the latter cold interval is a time known as the "Little Ice Age". As written on the subject of glacier lakes in the previous articles, the glacier lakes that dammed by moraines were formed during Holocene glacier expansion (between 3,000 and 150 years ago). Bhutan's mountains have many glacier land-

forms that are essential parts of the present beautiful mountain landscapes. Study of the past glaciations contributes to the understanding of the present mountain landscape, and it is especially critical for mitigating the risk of glacier hazards, such as glacier lake outburst floods.



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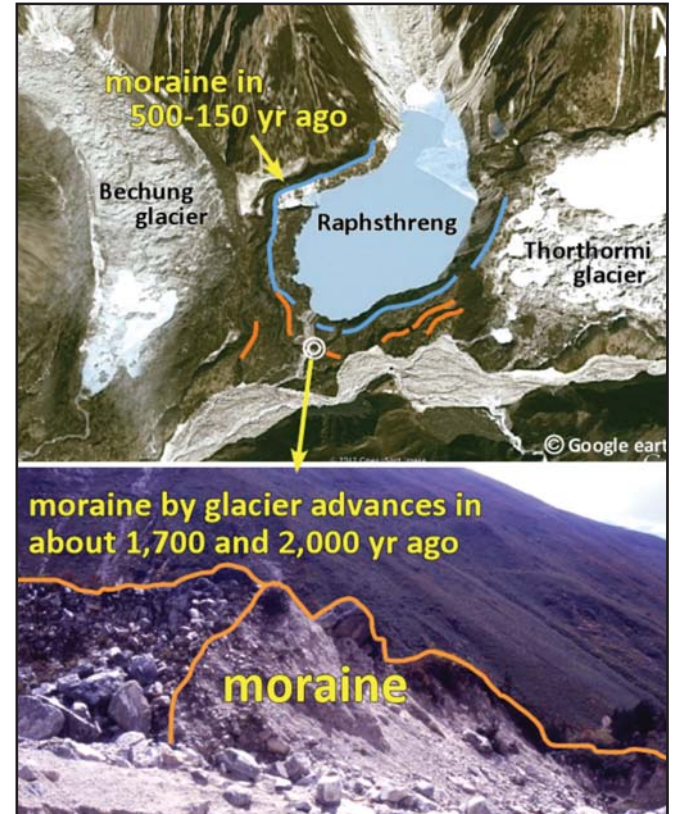


Figure 4. Raphsthreng Glacier Lake is dammed by several moraines