tephra was deposited directly on grassy meadow vegetation and preserved in permafrost (Figure 7). Fossil nests of arctic ground squirrels (*Spermophilus parryii*) and bones of the well-known Beringia "big-three", woolly mammoth (*Mammuthus primigenius*), steppe bison (*Bison priscus*) and Yukon horse (*Equus lambei*), are almost always found at sites with Dawson tephra. The 1300 year old White River Ash, seen commonly in highway cuts around Whitehorse and southern Yukon, comes from a vent at or near Mount Churchill in the Wrangell Mountains and marks one of the most extreme volcanic events since the end of the last ice age. It is useful to archaeologists because it marks a time of regional prehistoric technological change.

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March, 2009

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Yukon
Tourism and Culture

The Yukon Palaeontology Program's Beringian Research Notes series presents vignettes of life in the Yukon during the last Ice Age.

Beringian Research Notes

2009 No. 22

Figure 1: A vigorous eruption column rising over the summit of Augustine volcano on March 27, 1986. Note heavy tephra fallout to the left of the volcano. Augustine volcano is located in the lower Cook Inlet, Alaska, and is part of the eastern Aleutian volcanic arc. (Courtesy of the United States Geological Survey.)

Tephra in Eastern Beringia

One of the most fascinating fields of research for investigating ancient Beringia is the study of volcanic ash or "tephra". In recent years, scientists have been searching out and analyzing tephra deposits because they provide valuable time marker beds that help with the reconstruction of geological and environmental history in Beringia.

"Tephra" refers to all the fragmental material that is ejected from a volcano during an eruption. It consists of magmatic glass and crystals as well as broken up pieces of the volcano. Glass is typically the most abundant component (Figure 2). Very explosive volcanic eruptions eject tephra well into the upper atmosphere (10 to 50 km high) where it is carried by winds and eventually deposited on the landscape as an air-fall tephra bed, in some cases, more than a thousand kilometres from its source (Figure 3). In general, tephra beds become thinner and more fine-grained the farther they are from their source so that most areas of Alaska and

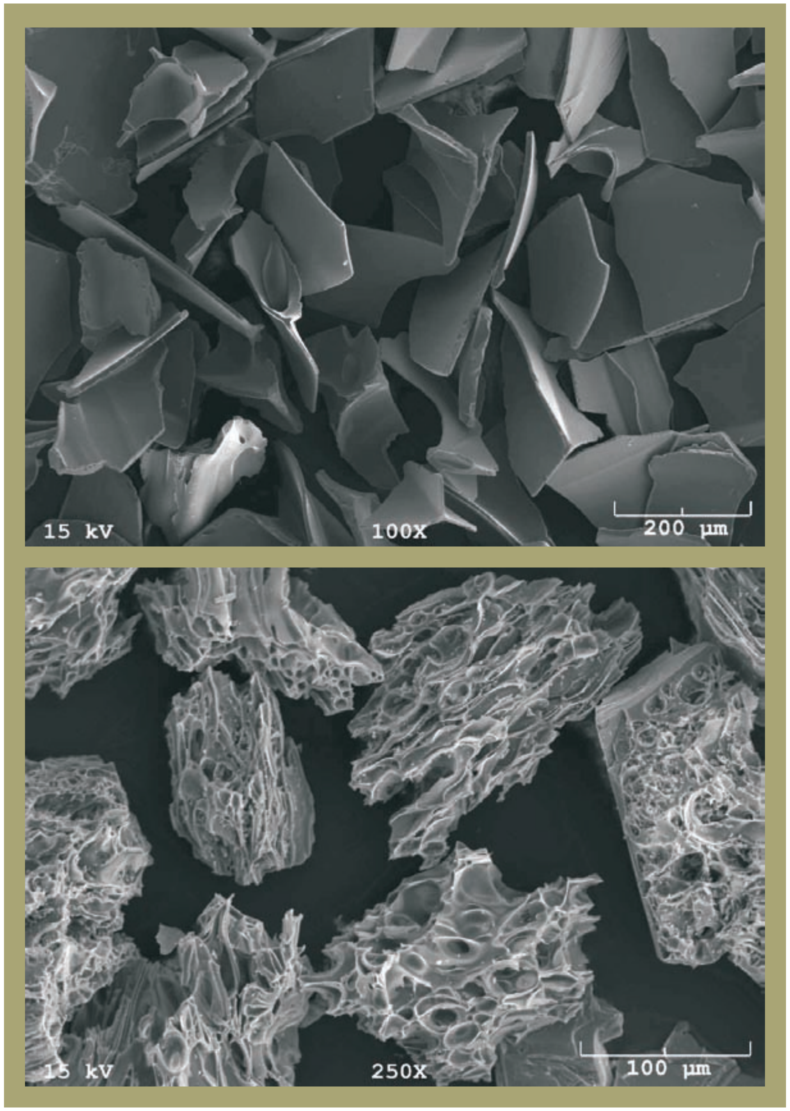

Figure 2: With a few exceptions, glass is the most abundant constituent of tephra beds. The shape of the glass grains can vary greatly from one tephra deposit to another depending on the composition of the magma and character of the eruption. Scanning electron microscope images show “bubble-wall” glass shards from Dawson tephra (A), and riddled pumice grains from the eastern lobe of White River Ash (B). Magnification and scale are shown on each image.

Yukon, being remote from volcanoes (Figure 3), have tephra beds that are typically fine-grained, thin, and discontinuous. An exception is the thick bed of Dawson tephra found in the Klondike goldfields (Figure 4), clearly the result of an extremely large volcanic eruption. Once deposited, the powdery tephra bed is very susceptible to removal by the downslope movement of soils and sediments (mass-wasting), running water, winds, and glaciers. By these means, the tephra particles become dispersed within the local sediments, in some places leaving

Figure 7: Grassy meadow vegetation that was buried by a thick bed of Dawson tephra about 30,000 years ago in the Goldbottom Creek valley, Klondike goldfields. Close physical examination of the tephra bed and associated ice lenses indicated that Dawson tephra blanketed the Klondike during a late Winter or early spring volcanic eruption. Analysis of the buried vegetation provided a detailed record of the environmental conditions at the onset of the last glaciation. (Photo by Grant Zazula.)

we see today in Yukon and grew in a climate that was much wetter and with less extreme temperatures. The demise of these preglacial forests was brought about by major cooling, causing the growth and advance of massive glaciers across southern and central Yukon sometime between 2.9 and 2.6 Ma.

Quartz Creek tephra, which is preserved in an ice-wedge cast at Quartz Creek in the Klondike goldfields, demonstrates that permafrost (perennially frozen ground) was established in Beringia by 3 Ma. At Fairbanks, Alaska, PA tephra reveals that Ice Age climates, characterized by cold temperatures and dry conditions, resulted in the accumulation of wind-blown silt (loess) at about 3 Ma. Large ice wedges, found in the Dominion Creek area of the Klondike goldfields, are blanketed by the 700,000 year old Gold Run tephra. The presence of ancient ice and frozen ground that is nearly three-quarters of a million years old indicate that permafrost in Yukon may be less susceptible to climate change than some scientists have anticipated. Old Crow tephra (about 130,000 years old; Figure 6), named for the region in which it was first identified, is recognized at several sites across Beringia and is commonly associated with fossil trees and boreal forest plants. Old Crow tephra is an effective marker bed for the Last Interglacial, which is the last time during the Ice Age when conditions were as warm as those of today. Dawson tephra (about 30,000 years old) is the most recognizable tephra bed in the Klondike (Figure 4), and acts as an excellent marker bed for the onset of cold, dry climates of the last glaciation in eastern Beringia. At Goldbottom Creek, Dawson found in a placer gold mine near Chicken, Alaska, provides an excellent marker for the unique forests that clothed eastern Beringia just before the Ice Age, about 2.9 Ma (million years ago). Pollen and plant fossils found with the tephra indicate that the forests were dominated by pine (*Pinus*), spruce (*Picea*), larch (*Larix*), and fir (*Abies*) trees. This boreal forest had a much greater diversity of plants than

Figure 6: The joy of discovery! Britta Jensen (University of Alberta) finds Old Crow tephra in organic-rich silts along bluffs of the Porcupine River, near the village of Old Crow, Yukon. This tephra bed tells her that she is looking at sediments deposited about 130,000 year ago, just before the last interglacial period.

no trace of the former discrete bed. Preservation of the tephra bed is favoured by rapid burial or deposition in low-energy environments such as deep lakes and peatlands. Consequently, a tephra bed is only patchily preserved over its fall-out zone (Figure 3).

A rich archive of late Cenozoic (last three million years) tephra beds is found in eastern Beringia, the result of long-term explosive volcanic activity in the Aleutian arc –z Alaska Peninsula (AAAP) region and the Wrangell volcanic field (WVF) (Figure 3) and the fact that much of eastern Beringia escaped the powerful erosive action of glaciers during the Ice Age. These tephra beds can be seen in sediments exposed in bluffs along the many river valleys, some along the valley bottoms, others on the higher terraces. The best records of tephra beds presently known in eastern Beringia occur in the Klondike (Yukon) and Fairbanks (Alaska) goldfields. Although we know the source volcanoes are located in AAAP and WVF, only rarely has the parent volcano of a particular eruption been identified (Figure 3).

The usefulness of tephra beds can be fully realized only when we know their respective ages and distinguishing features. Discovery of a thin tephra bed in itself does not tell us much – simply that a volcanic eruption occurred and dumped tephra at that spot. No tephra bed is exactly the same as another in terms of its characteristics and context in the host sediments. This is true even for tephra

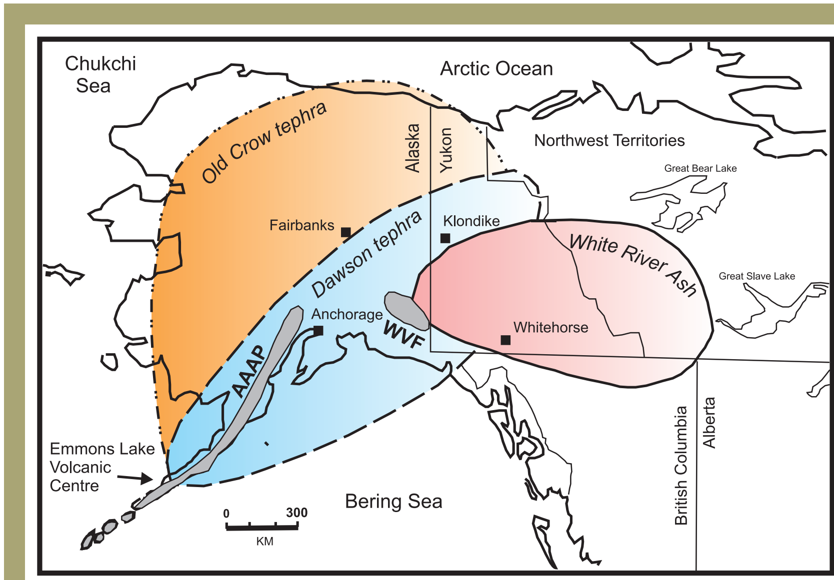

Figure 3: Distribution of Old Crow tephra (~130,000 years old), Dawson tephra (~30,000 years old), and White River Ash (east lobe, ~1300 years old) in eastern Beringia (Alaska and Yukon). The extent of White River Ash is well constrained by numerous tephra occurrences, but the distribution of the other two tephra beds is poorly constrained. White River Ash comes from a vent at or near Mount Churchill in the WVF, Dawson tephra from the Emmons Lake Volcanic Centre in the AAAP, and the compositional similarity of Old Crow tephra to Dawson tephra suggests the same or a nearby source. AAAP is the Aleutian arc – Alaska Peninsula volcanic provenance, and WVF is the Wrangell volcanic field.

Figure 4: A thick occurrence (up to 70 cm) of Dawson tephra at Quartz Creek, Klondike goldfields, Yukon. Thicknesses in the range of 10 – 30 cm are not uncommon for Dawson tephra in the Klondike goldfields and indicate a very large volcanic eruption because the source volcano is located in the Emmons Lake Volcanic Centre, Alaska, about 1500 km away.

erupted at different times from the same volcano. Reliable identification of a tephra bed requires use of a detailed set of criteria. Features noted in the include bed thickness, colour, and coarseness, together with the type of host sediment, position in relation to other tephra beds and other sedimentary layers or soils in the exposure. The shape of the glass particles in the tephra bed (Figure 2), kinds of minerals present, and the elemental composition of its glass and minerals are all determined in the laboratory, using microscopes and other instruments. Glass composition is especially useful for identifying tephra beds, as can be seen in Figure 5. Fortunately, there are a number of techniques that can be used to determine the age of tephra beds, either indirectly by using nearby material (e.g. radiocarbon age of organic-rich soils, fossil bones or plants), or directly, by using the constituents of the tephra bed (e.g. fission tracks in glass). Magnetic properties of the surrounding sediments are also useful in determining the identity and age of tephra beds. All these attributes, taken together, provide a unique signature for a given tephra bed, enabling its recognition elsewhere.

Armed with this information, how does the study of tephra beds help our understanding of the geology, archaeology, palaeontology, and ecology of Ice Age Beringia? Since explosive volcanic eruptions last no more than a few days, tephra beds represent an instant of geologic time. Hence, if their age and identity can be established, they make excellent marker beds, permitting correlation of soils, sediments and fossils between sites, sometimes over vast distances (Figure 3). In other words, sediments, soils, and fossils found at different sites with the same

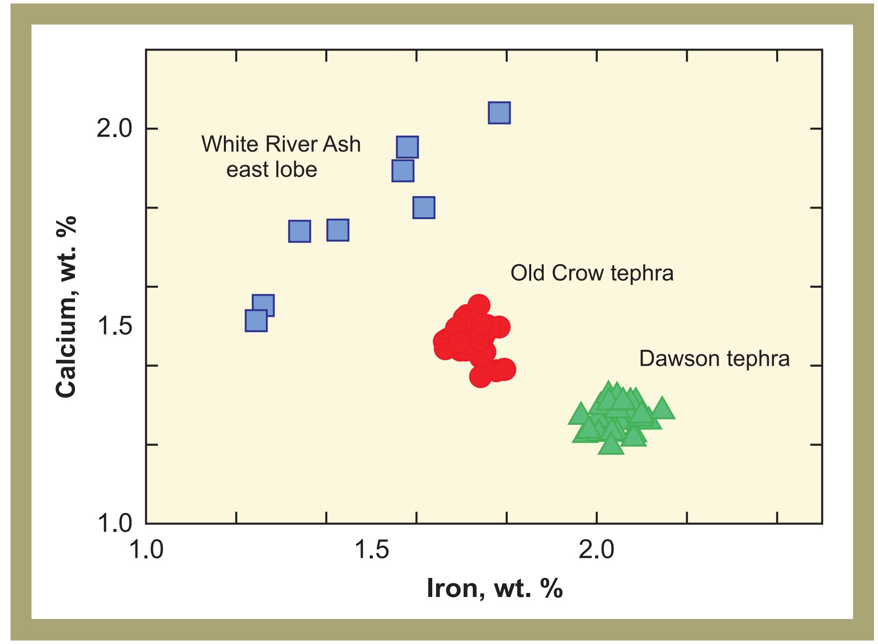

Figure 5: The chemical composition of glass shards in tephra (volcanic ash) beds can be very useful for discrimination purposes. Each spot on this figure represents the composition of an individual glass shard. White River Ash (east lobe) shows a relatively large compositional spread compared to the other two tephra beds, all three having very distinctive iron and calcium concentrations.

tephra bed are of the same age. Furthermore, tephra beds in eastern Beringia are typically light-coloured, making them easily visible in the field (Figure 6). They have enabled isolated exposures of sediments with their contained fossils to be linked and ordered according to their age, facilitating reliable reconstruction of the regional geological history, including the story of past environmental change. Work of this nature is currently being done in the Klondike goldfields, which have an abundance of mining cuts with tephra beds. Without tephra beds, integration of the geological information into a regional story would be much more difficult. Of course, tephra beds also provide useful information for the study of volcanoes. Volume of tephra erupted, direction and velocity of winds, height of the eruptive column, duration of the eruption, and the eruption rate can all be derived from the physical characteristics of the tephra bed across its fall-out zone. An additional asset of distal tephra beds, such as those preserved in the late Cenozoic sediments of interior Alaska and Yukon, is that they record a more complete history of explosive volcanic activity than that available in the source regions, in this case the AAAP and WVF (Figure 3). This is because some of the lava and tephra deposits at and near the volcanoes are removed during violent eruptions. High altitudes, rigorous climate, and steep slopes all lead to rapid erosion of volcanoes, adding to depletion of the rock record in the source areas.

A few examples highlight the positive impact of tephra studies on Beringian research. Its recent integration with palaeoenvironmental studies has vastly improved our knowledge on the timing of dramatic environmental changes in eastern Beringia during the last three million years (Figure 7). Lost Chicken tephra,