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ARCTIC

Arctic Research Consortium of the United States Member Institution Spring 2002

Arctic Research at the Louisiana State University

by H. Jesse Walker

Years before arctic research became formalized at Louisiana State University (LSU), archaeologist James Ford worked on St. Lawrence Island and at Point Barrow, Alaska (1930–56); geographer Fred Kniffen was in Alaska (1922–24); and geographer Richard Russell and geologist Henry Howe were in Novaya Zemblya (1937). These pioneers relayed their experiences to their students, two of whom—Jesse Walker and Fred Hadleigh-West—did LSU's first arctic dissertations in the 1960s on the interactions of indigenous peoples with their arctic environment.

Ice Island Research

In 1952, 15 years after Russians had pioneered the use of Arctic Ocean ice as a base for research, Americans established their first drifting station on Fletcher's Ice Island (T-3). In 1958, as part of the International Geophysical Year Program, the U.S. Air Force Cambridge Research Center initiated a major research effort on T-3, including a geomorphology study conducted by David Smith (Dartmouth College). Smith transferred to LSU, continued his T-3 work, and in 1961, conducted geologic/glaciologic field work on the Arctic Research Laboratory Ice Station, II (ARLIS II). Like T-3, ARLIS II had fractured from Ellesmere Island; unlike T-3, it had prominent rock-covered, ice-cored hills. Smith deciphered the complicated glacial ice, iced firn, lake ice, sea ice, and morainal character of the island.

Floodwaters at the mouth of the Colville River delta in 1971. The LSU research team calculated that 10 days of flooding during breakup that year contributed 4.64 x 10^9 m^3 of freshwater—nearly half of that year's total discharge—as a freshwater wedge beneath 3,000 km^2 of sea ice (photo by Donald Nemeth).

The Coastal Studies Institute and Arctic Research

In 1954, the LSU Board of Supervisors established the Coastal Studies Institute (CSI) as an affiliated unit in the School of Geology, which encompassed studies in geology, geography, and anthropology. Russell was its founding director. Funded primarily by the U.S. Office of Naval Research (ONR) through its geography programs, CSI was interdisciplinary and field-oriented with emphasis on coastal forms and processes. After several years of coastal research along the U.S. Gulf Coast, and in Europe, Asia, and South America, CSI expanded to other areas of the world including the Arctic. In the 1960s and 1970s, CSI initiated two major arctic endeavors:

- a multifaceted, long-term study of the Colville River Delta (1961–78), and
- a broader-based program addressing Alaskan Arctic Coastal Processes and Morphology (1971–73).

ONR supported both of these programs under the supervision of Louis Quam, Evelyn Pruitt, and Max Britton. The Naval Arctic Research Laboratory (NARL), directed by Max Brewer and John Schindler, provided logistical support.

Published by the Arctic Research Consortium of the United States • 3535 College Road • Suite 101 • Fairbanks, AK 99709

The Colville River Delta Studies

Some of the most distinctive deltas on Earth are found in the Arctic. In 1960, CSI selected the moderately sized (~670 km^2) Colville River delta in Alaska for detailed study. Little known outside the Iñupiat community and mentioned briefly in the journals of only a few explorers (*e.g.*, Vilhjalmur Stefansson), the Colville River delta was scientifically a *terra incognita*. In March 1962, after reconnaissance in 1960, CSI launched a cryologic/hydrologic/ geomorphic field investigation by a team composed of Lennart Arnborg and Johan Peippo (University of Uppsala, Sweden), Jesse Walker and Morris Morgan (LSU), and members of the George Woods family who lived on the delta.

Colville River Discharge

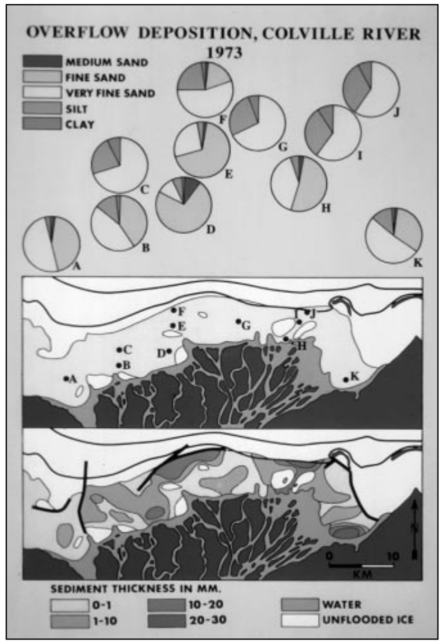
Prior to breakup (April–May 1962), the team monitored the ice and water regime of the Colville River from the ocean to 80 km upstream. Their observations that season included:

- no measurable flow in the river;
- a saltwater wedge extending 64 km upstream from the ocean;
- ice ~2 m thick—not thick enough to freeze to the bottom of the deepest part of the main channel, but thick enough to freeze portions of the west channel to the bottom, creating pockets of highly saline water (40–60‰);
- during high stages at breakup, the eastern channels carried some 70% of the water, Nechelik channel carried 20%, and other distributaries carried 10%; and
- during summer, generally the time of low discharge, the eastern channels carried about 77% of the discharge and the Nechelik channel about 22%.

Several seasons of study indicated that breakup occurs near the time of maximum stage. Ice jams are more common when breakup occurs on a falling stage than on a rising stage. Flood waters flow over bottom-fast river ice and also out over bottom-fast sea ice (see photo page 1).

Suspended Load in the Colville River

The research team also measured or calculated dissolved, suspended, and bed loads in the Colville River. Fine sediments deposited on the riverbed during the low flows beneath winter ice are the first to be entrained during the flood season. In 1962, some 5.8 x 10^6 tons of suspended inorganic material and 1.3 x 10^6 tons of dissolved salts were transported past the head of the delta. Of the total annual suspended load, 62% was transported in the 13-day breakup period.



The Colville River is one of many that flow from the Brooks Range to the Beaufort Sea, delivering freshwater and sediment loads that distinguish the Beaufort Sea ecosystem from that of the Chukchi Sea to the west. This chart maps sediment deposited on sea ice during flooding in 1973 (figure by H. Jesse Walker).

Channel Morphology

Echo-sounding of the river's channels (245 cross-sections in the two main channels and longitudinal profiles of the thalweg of other distributaries) revealed that channels were more than 12 m deep along cutbanks and at the mouths of tapped lakes and more than 1 km wide in some places. The nearly 500 km of channels include 53 bifurcations and 29 rejoinings, providing 5,200 possible routes to the sea.

Permafrost, Ice Wedges, and Bank Erosion

The Colville River and its delta are in the zone of continuous permafrost, where ice wedges are a common feature. High water often flows against a frozen bank with embedded ice wedges, carving a thermoerosional niche that undercuts as far as 8 m laterally into the frozen ground. The large hanging blocks may collapse, frequently along ice wedges, which are lines of weakness within the permafrost. This results in a major rate of bank retreat. Monitoring of bank retreat within the delta began in 1962 and continued into the mid-1990s.

In 1971 and 1973, teams of scientists, graduate assistants, and technicians turned their attention to the oceanography of the delta. The researchers calculated total freshwater discharge indirectly, by measuring the development of the freshwater wedge beneath the ice from stations they established on the sea ice at the front of the delta. In 1971, they occupied 29 stations a total of 59 times. In 1973, they occupied 56 stations 155 times and made another 54 observations and calculations at river sites. In 1971, 10 days of flooding during breakup spread 4.64 x 10^9 m^3 of freshwater—nearly half of the year's total discharge—across the bottom-fast sea ice at the front of the delta and then beneath about 3,000 km^2 of floating sea ice (see photo page 1).

Investigators measured the salinity and temperature of the sub-ice water column and took samples to determine the suspended load and the role of the river as a nutrient source during spring flooding. They found that breakup flooding raised the inorganic nitrogen:phosphate ratio to a state that was nutrient-balanced for phytoplankton in the nearshore waters of the Beaufort Sea.

Additional Colville River delta research during the early 1970s included:

- a detailed analysis of the processes and forms occurring on an arctic river bar (Lawrence Mckenzie, III);
- deposition on sea ice during flooding (Charles Wax);
- grain-size characteristics and fluvial processes on mid-channel gravel bars (Donald Nemeth); and
- the microclimate in a deltaic setting (Jeffrey Peake).

These studies earned the authors advanced degrees.

In 1971, William Ritchie (University of Aberdeen, Scotland) studied 170 riverbanks along the main channels. He noted that 59% of the riverbanks were erosional, 35% depositional, and 6% neutral. Righthand banks were 72% erosional; left-hand banks were only 46% erosional.

Other long-term field studies addressed:

- development of the active layer within sand dunes at the head of the delta (Walker and Harris, 1962–73), and
- the mapping of delta lakes as they were tapped by migrating river channels (Walker and Roselle, 1962–88).

Other Deltaic Research

Other arctic delta studies included:

- a morphologic and hydrologic study of the Blow River delta in Canada (James McCloy and Hyuck Kwon, 1967);
- an analysis of the structure and composition of deltaic sediments (Werner Furbringer, 1973);
- a classification of deltaic lakes (Alastair Dawson, 1975); and
- a classification of ice-wedge polygons using aerial photographs and Landsat digital data (Joann Mossa, 1983).

In the 1990s, more focused research led by Torre Jorgenson of Alaska Biological Research (ABR), Inc. built on results of the LSU Colville delta projects. The work by ABR addressed the environmental and engineering challenges of developing the Alpine oilfield in the dynamic deltaic terrain.

A few studies were more broadly based than the deltaic studies. Both Joseph Crotts (1972) and Chao-yu Wu (1983), for example, made morphometric analyses of the Colville drainage basin, and Walker (1973) worked on the morphology of the North Slope, including the small landforms present in the landscape.

The Colville River delta research resulted in more than 75 articles, monographs, and reports, as well as 12 theses and dissertations. Much of the material is available on the LSU web site (www.lsu.edu/diglib) under "Colville River Delta" in "Collections."

Ice wedges in peat banks melt more rapidly than the peat surrounding them erodes, leaving a riverbank that is serrated (photo by H. Jesse Walker).

Alaskan Arctic Coastal Processes and Morphology

Between May 1971 and June 1973, CSI conducted a study of the variability—both temporal and spatial—of the environment and physical processes of the Alaskan arctic coast. The intent was to characterize the interactions between the two fluid components of the environment—the ocean and the atmosphere—and between the two solid components—the land and the ice. Two sites—Point Lay on the Chukchi Sea, and less accessible Pingok Island in the Beaufort Sea—were chosen for detailed study of near-shore processes. Researchers analyzed existing data from arctic Alaska and made aerial field reconnaissance trips during breakup, open water, and freeze-up.

Atmospheric Processes

The objective of this study was to gather data at the Earth's surface in order to better understand the way the atmosphere affects the dynamic aspects of coastal processes. Shih Hsu and C. D. Walters, Jr., established wind-profile stations at Point Lay and on Pingok Island. They found that between wind speeds of 1–9 m/s (approximately 2.25–20 mph), the drag coefficient was approximately 1.7×10^{-3} for air-sea momentum transfer in the Chukchi Sea under summer conditions.

They also determined the vertical structure of wind across a sea-ice pressure ridge under winter conditions. They found that high-velocity air flow developed between the crest of the pressure ridge and one meter above it—a jet that contrasted with logarithmic wind profiles over smooth ice. This research, along with a similar study at a coastal dune site in Texas, led to the modification in the basic airflow models that were extant in the 1970s.

Subsequent to the field investigations of 1971–72, William Wiseman, Jr., and Andrew Short analysed Distant Early Warning (DEW) Line temperature records and concluded that:

- temperature variations on time scales of less than a month are larger in winter than summer;
- large warming trends occur between late fall and early spring; and
- temperature variation may have a periodicity of 45 days (based on spectrum analyses).

Nearshore Hydrodynamic Processes

Under the supervision of Wiseman and Joseph Suhayda, the CSI group selected four nearshore hydrodynamic phenomena for concentrated study:

- sea-level variations,
- wave motion,
- mesoscale currents, and
- mesoscale water-mass variability.

Among other things, the investigators observed meteorological tides greater in magnitude than astronomical tides. Energy input to the coastline was especially great during storms (*e.g.,* alongshore wave power was 2×10^8 ergs/sec/cm, contrasted with 1×10^6 ergs/sec/cm under non-storm conditions). Such contrast is reflected in a sediment transport ratio of 1:142 (*i.e.,* one day of that storm transported as much sediment alongshore as 142 days of transport under average wave conditions).

Wiseman and Suhayda also observed that the flushing of coastal lagoons introduced sediment as well as freshwater into the nearshore system. The lower salinities of this inlet water affected the timing of freeze-up at their mouths and alongshore.

Alaskan Arctic Coastal Morphology

The CSI morphological study (1971-73) encompassed 1,441 km of coastline from Point Hope to Demarcation Point. Principal investigators James Coleman, Andrew Short, and Lynn Wright identified 22 landform "provinces"—barrier islands characterized 56% of the coast, tundra bluffs 27%, deltas 9%, and rocky cliffs 8%.

Macroscale variability of the coast is the result of geologic structure, river distribution, oceanic circulation, thermal regime, ice-pack conditions, open-water periods, and wave power. A major difference between the Beaufort and Chukchi coasts is that all of the major rivers of the North Slope drain into the Beaufort Sea—affecting the development of deltas and the introduction of sediment into the Arctic Ocean. Compared to the Beaufort Sea coast, along the Chukchi Sea coast:

- breakup was earlier,
- open water lasted longer and covered a larger area, and
- wave energy was greater.

Beach Processes and Responses

The CSI team studied beach process-response interactions in the context of breakup, open water, and freeze-up. River-ice breakup precedes sea-ice breakup, often by weeks. Beach thaw is highly variable; timing and extent depend largely on wave conditions during freeze-up, as ice incorporated into the beach during storms affects beach thaw and beach morphology.

A study of ice movement revealed differences seaward and landward of an offshore bar because of the interaction between waves and tides and the bottom topography. Fathometer profiles at Pingok Island revealed four bars with steep shoreward slopes and gentle seaward slopes, intersecting the shoreline at an angle between 8° and 10°. These arctic bars were the first known evidence of outer bars consistently extending to and actively modifying the shoreline in the absence of inner bars.

Onshore beach ridges were well preserved compared with similar features in other climates because:

- severe storms are rare,
- the ridges are frozen 10 months/year,
- a gravel pavement on their surface reduces deflation, and
- swales full of water during summer undergo little eolian erosion.

Subsequent Coastal Research

Although the above represents the active field and laboratory phase of CSI's Alaskan Arctic Coastal Processes and Morphology Study, many of the principals of that group extended their involvement:

- Short and Wright identified two major sets of lineaments on the North Slope and suggested that there is a direct association between them and arctic coastal morphology;
- Short demonstrated the role of offshore standing waves in controlling the pattern of sand bars;
- Harper and Wiseman wrote on the temporal variation of surface roughness on a tundra surface;
- Harper completed a dissertation on the physical processes affecting tundra cliff stability;
- Douglas Fisher investigated active layer development on a barrier island; and
- CSI and Department of Geology personnel, especially Wiseman, Don Lowe, and David Prior, studied slope instabilities in arctic and sub-arctic fjords, which cause some of the most intense currents observed in deep fjords. ■

Environmental Geomorphology

Development of the petroleum industry and modernization of North Slope villages since the 1970s brought large demands for sand and gravel. The NSB opted to use unfrozen deposits beneath deeper rivers, lakes, lagoons, and nearshore ocean waters. Dredging began in 1981 on the Colville River delta. The NSB Public Works Department initiated environmental monitoring, with which Jesse Walker was associated from 1980 to 1994, noting alterations in the tundra surface after runway construction and changes in the dredge channels in the Kokolik, Meade, and Colville rivers. ■

An unabridged version of this overview of LSU research in the Arctic is available on the ARCUS web site at:

www.arcus. org/Witness_the_Arctic/Spring_02/Contents.html

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Arctic Biology

Since 1980, a team from LSU's Department of Comparative Biomedical Sciences—Yahya Abdelbaki, Dennis Duffield, Jerrold Haldiman, William Henk, Robert Henry, Daniel Hillmann, and Diana Mullan—has been leading a study to collect baseline data on the anatomy of the bowhead whale *(Balaena mysticetus)* prior to potential environmental alteration. They are studying the anatomy of the lungs, kidneys, eyes, hearts, and brains, and the structure and thickness of the skin of whales harvested by Iñupiat and Yupik Eskimos off at least six coastal villages.

This is one of many research projects in arctic Alaska that have involved residents (*e.g.,* whaling captains and crews), and it reflects the Inuit's concern for their environment. Sponsors have included the U.S. Bureau of Land Management; the NSB, the Chinese Academy of Sciences, and the LSU School of Veterinary Medicine.

LSU is also involved in long-term research on the population biology of geese at Karrak Lake in Nunavut, Canada. Alan Afton (LSU's Biological Resources Division) has been a visiting research scientist with the Canadian Wildlife Service since 1993. Along with graduate students, he is focusing on the behavioral aspects, foraging ecology, and nutrition of Ross's geese *(Chen rossii)* and lesser snow geese *(Chen caerulescens caerulescens)*. ■

LSU Comparative Biomedical Sciences researchers collect baseline data on the dimensions of the skull of a bowhead whale harvested by North Slope residents at Barrow, Alaska (photo by Daniel Hillmann).