Ice Covered Lacustrine Processes: Insights from Antarctica relevance to Eberswalde Lake

Jim Rice
NASA GSFC

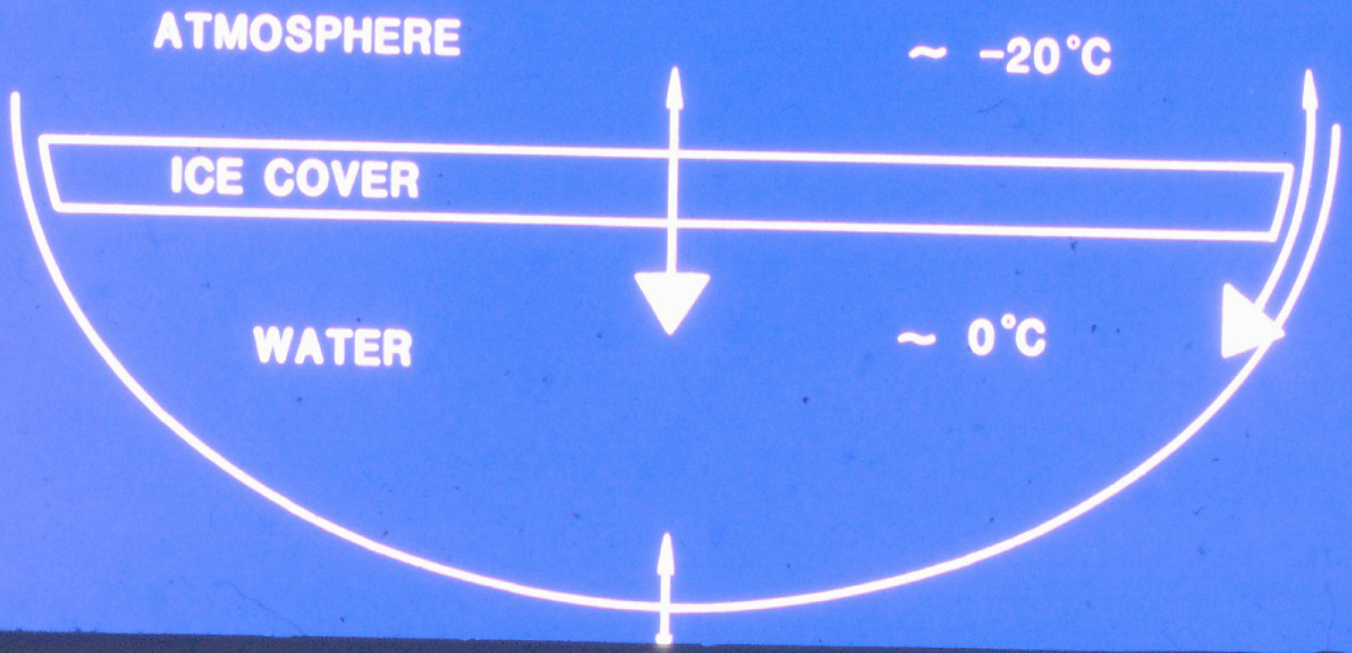
Antarctic perenially ice covered lakes

- Mean air temp -30°C, low precipitation (1-2 cm water equivalent, snow)
- Ice cover 4-19 m thick, lake water depths up to 120 m (Fresh to super saline water)
- Primary energy input into lake is latent heat carried by the inflowing meltwater. This latent heat is released when water freezes at bottom of ice cover.
- Lake water temp 0 to -3°C, gases supplies by inflow of aerated summer meltwater (2-3 weeks/yr), ice cover traps gases (supersaturated O_2 400% and N_2 160%) , only ½ of O_2 from biology
- Less than 1% photosynthetically active radiation (0.4-0.7 micron wavelenght) penetrates ice cover
- Closed lacustrine basins, water loss mainly thru ablation (~20 cm/yr) of ice cover and some evaporation from narrow shore marginal moat of open water (summer)
- Shoreline/beach is coarse poorly sorted with boulders up to 4 m diam
- Cyanobacterial, Phormidium frigidum, mats (cold water stromatolites) adapted to near freezing temps and low light cover lake bottoms,

Important Properties of Ice-covered Lakes :

1) Thermal buffering.

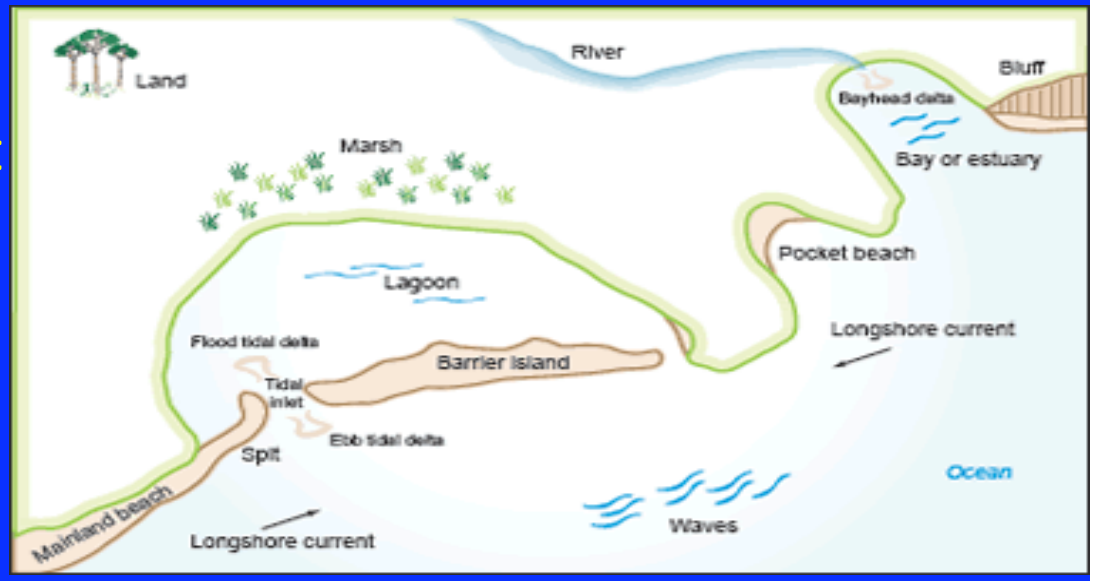
2) Mechanism for concentrating biologically important gases.



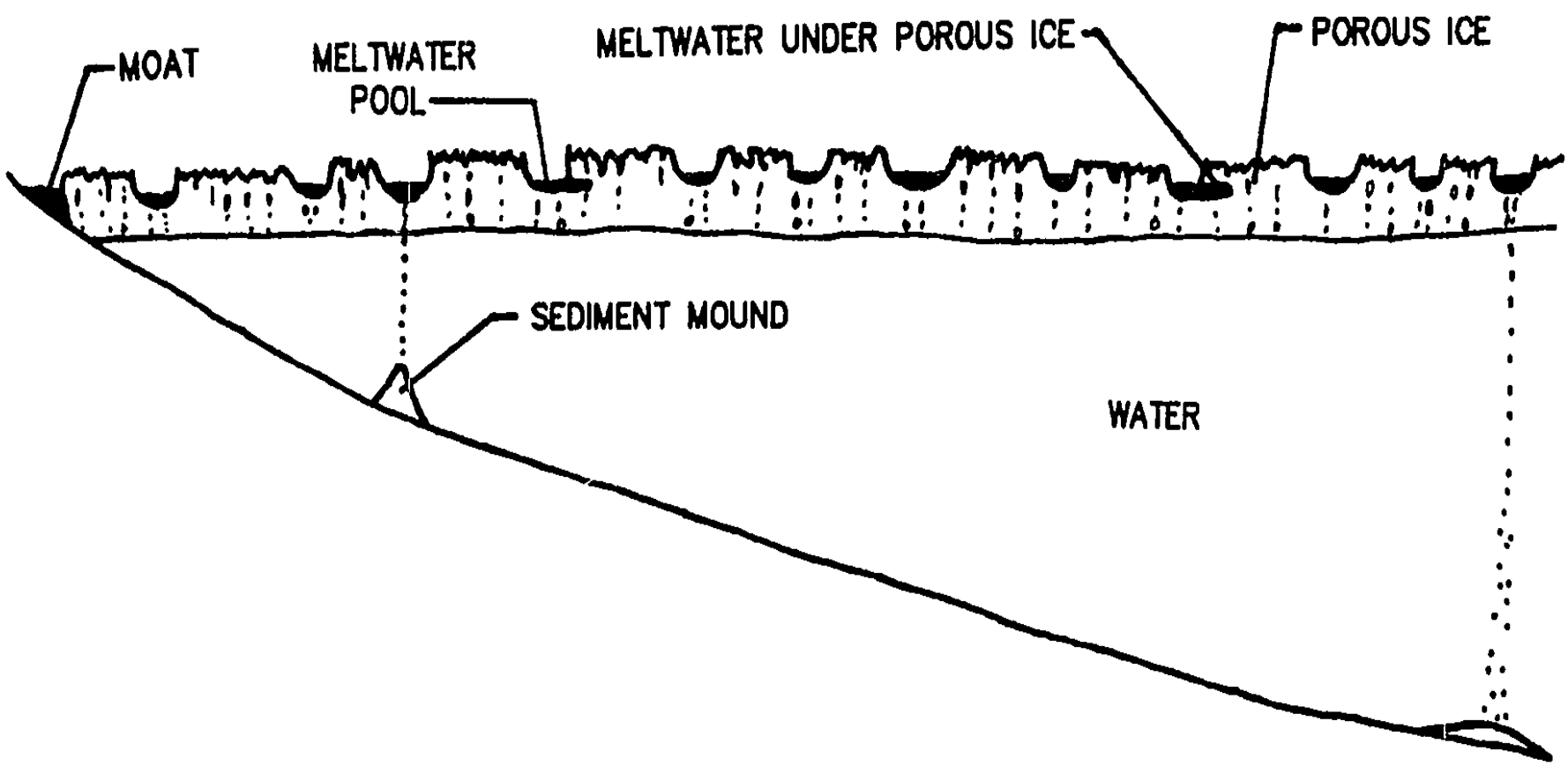
Classic Coastal Landforms and Processes

Waves:

1. Erode coastal rock/sediment
2. Transport sediment from coastal erosion & sediment supplied to coast by rivers
3. Deposit sediment in low energy coastal environments



- Erosional: Wave cut terraces/ platforms, sea notches/cliffs/ arches/caves
- Depositional: Barrier islands, spits, tombolos

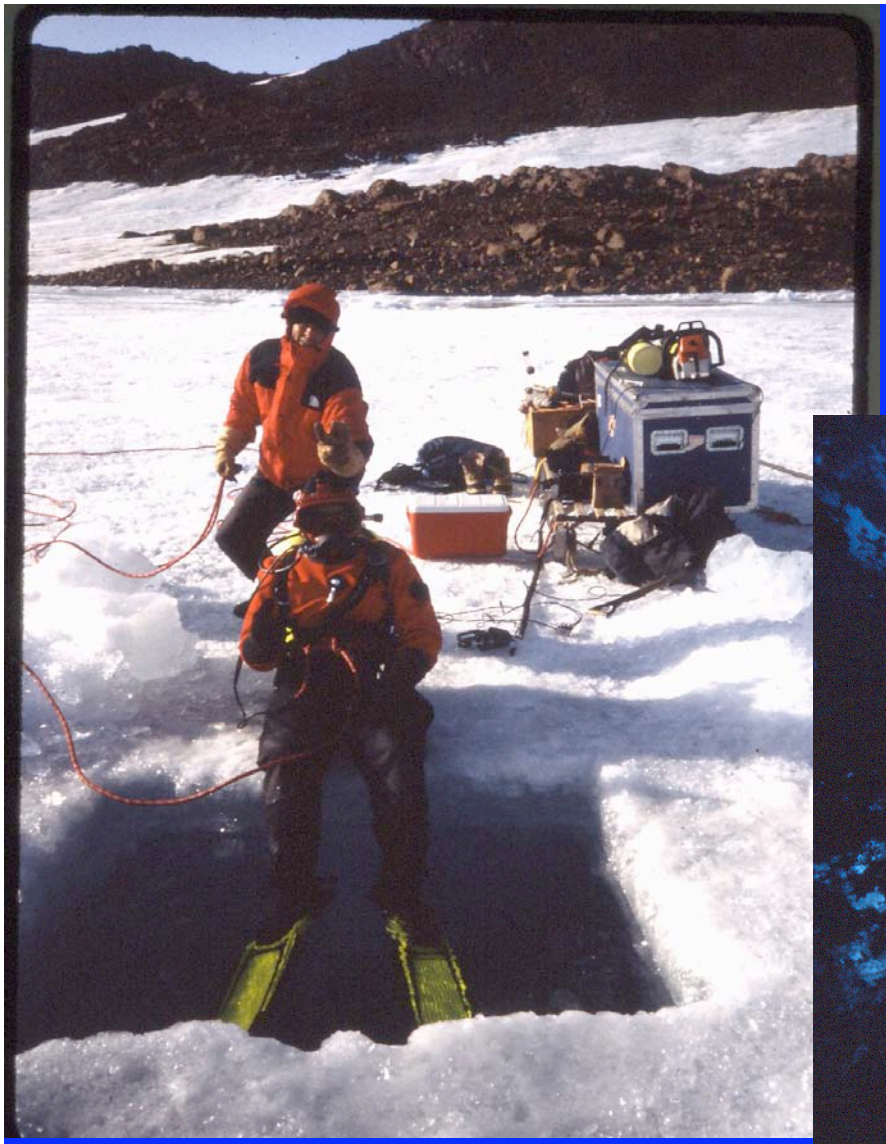


Perennially ice covered lake and sediment release mechanisms.

(Modified from Shackman, 1994)

Sedimentary processes of thick perennially ice covered lakes

- Rough lake ice surface forms ice ridges 1 m high and troughs 10 m wide, (ablation tables from differential heating sediment/rocks) traps windblown sand, that then migrates downward thru ice cover via vertical conduits (ice fractures, discrete bubble columns, coalesced bubble columns forming large sand floored chambers)
- Fractured ice release of large quantities of sediment/rocks (gravel-boulder sizes) forms conical mounds (up to 2 m high; 3 m diam; slopes up to angle of repose) and ridges (35 m long, 40-50 cm wide) called dump structures on lake bed.
- Mounds: clays and poorly-moderately sorted sandy gravel to pebbly sand, sands are subangular to subrounded, stratified to non stratified



Sedimentary processes of thick perennially ice covered lakes

- Highly localized sedimentation (clays, sands, gravels form mounds and ridges, composite mounds) from dumps, normally graded (instantaneous deposition)
- Settling velocities of sand at 0°C ranges from 0.2 cm/sec for very fine sand to 25 cm/sec for very coarse sand. For water depths of 25 m 90 seconds for coarse grains and 3.5 hours for fines to settle to bottom.
- Non mounded non graded clay and sand units of uniform thickness dominate (grain by grain release from ice)
- No lakewide correlative layer recognizable in any of our diver collected cores (sedimentation rates appear to be controlled by amount of sediment available and thickness of ice cover)
- Lakes with thinner ice covers (<3m) have somewhat more correlative deposits, thicker ice covered lakes have more localized sedimentation

The question of shorelines or lack thereof


marine terrace
wave - cut
platform

Cold Coastal Processes and Products

Display extraordinary variety of geomorphic features and sedimentary structures attributable to perennially ice covered bodies of water. Ice cover prevents wave action thus shoreline/beach development is negligible to non existent. Ice cover is dominate control on coastal morphology

- **ice rafting, ice pushed ridges and levees, cobble pavements, boulder ramparts, boulder barricades and garlands, boulder strewn flats and platforms, shorefast ice (30km)/ prodelta strudel scour (10m diam; 2m depth), finger deltas, ice melt collapse structures (kettle holes)**

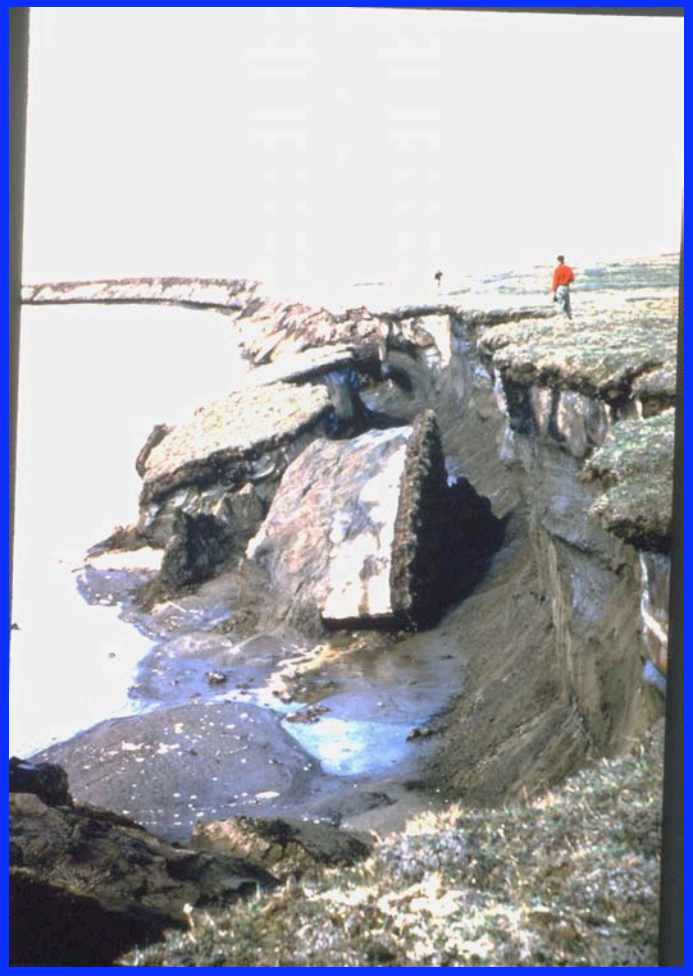
Cold Coastal Processes and Products

- Cold beach gravels subangular to angular and poorly sorted compared to temperate beaches
- Thermal expansion and/or wind stress induces horizontal motion of lake ice creating grooved scour marks, ice pushed sediment ridges (90 m inland, up to 5-10 m high), cobble pavements, boulder ramparts (2-3 m high, 100's m length segments)
- Ice bulldozes, mobilizes, resuspends and rafts sediments and clasts (up to boulder size, 3-4 m)

Ice pressure against coasts varies widely, some regions are heavily impacted by ice ride-up and pile up processes while other coastal sections nearby display little evidence of ice interaction.

Ice rafted and dropped clasts (drop stones) and subaerial pyroclastic bomb sags

- Bedding under clasts can be penetrated, dragged down and thinned, folded or show microfaulting while onlap of sediments occur above clasts
- Dropstones: vertical 'slow motion' fall thru water column produces symmetric deformation hollow
- Bomb Sags: Ballistically ejected volcanic clasts typically form asymmetric deformation hollow reflecting angle and direction of impact. Width-depth of disturbance from ballistic impact is function of projectile mass, momentum, and angle of impact
- Width-depth ratios of pyroclastic bomb sags differ greatly from dropstones in water



Martian Ice Covered Lakes

- Modeling results suggest that ice-covered lakes on Mars could have persisted 260-500 million years (McKay et al., 2005), if there was a source to provide meltwater.