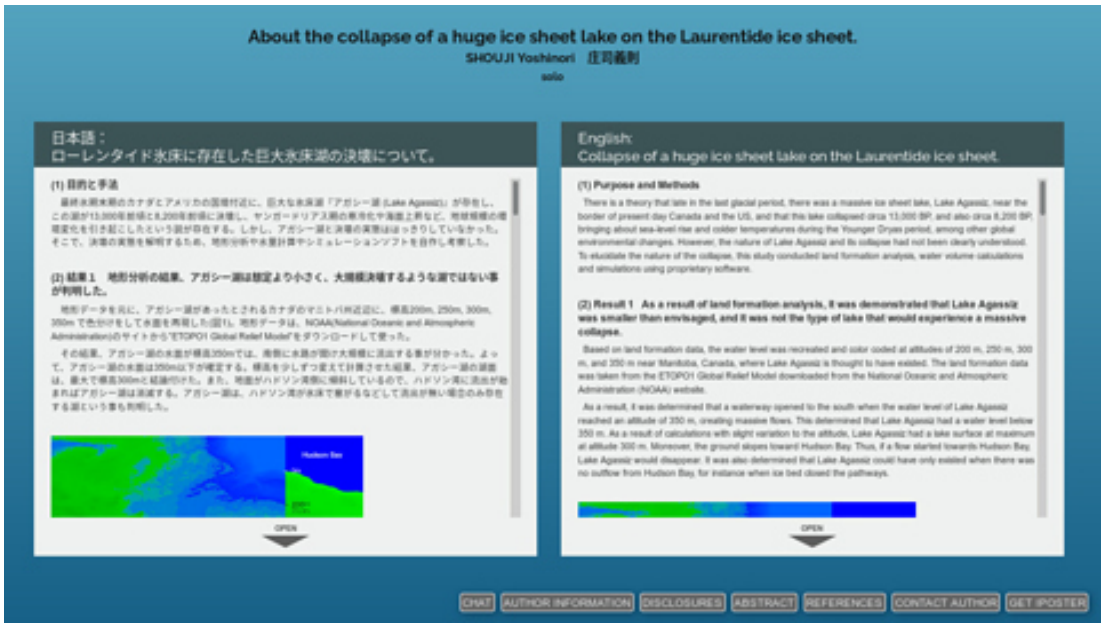
About the collapse of a huge ice sheet lake on the Laurentide ice sheet.



SHOUJI Yoshinori 庄司義則

solo

PRESENTED AT:

JpGU AGU2020 VIRTUAL MEETING 12–16 JULY

JpGU - AGU Joint Meeting 2020

For a Borderless World of Geoscience

Japan Geoscience Union, American Geophysical Union

ENGLISH:
COLLAPSE OF A HUGE ICE SHEET LAKE ON THE LAURENTIDE ICE SHEET.

(1) Purpose and Methods

There is a theory that late in the last glacial period, there was a massive ice sheet lake, Lake Agassiz, near the border of present day Canada and the US, and that this lake collapsed circa 13,000 BP, and also circa 8,200 BP, bringing about sea-level rise and colder temperatures during the Younger Dryas period, among other global environmental changes. However, the nature of Lake Agassiz and its collapse had not been clearly understood. To elucidate the nature of the collapse, this study conducted land formation analysis, water volume calculations and simulations using proprietary software.

(2) Result 1 As a result of land formation analysis, it was demonstrated that Lake Agassiz was smaller than envisaged, and it was not the type of lake that would experience a massive collapse.

Based on land formation data, the water level was recreated and color coded at altitudes of 200 m, 250 m, 300 m, and 350 m near Manitoba, Canada, where Lake Agassiz is thought to have existed. The land formation data was taken from the ETOPO1 Global Relief Model downloaded from the National Oceanic and Atmospheric Administration (NOAA) website.

As a result, it was determined that a waterway opened to the south when the water level of Lake Agassiz reached an altitude of 350 m, creating massive flows. This determined that Lake Agassiz had a water level below 350 m. As a result of calculations with slight variation to the altitude, Lake Agassiz had a lake surface at maximum at altitude 300 m. Moreover, the ground slopes toward Hudson Bay. Thus, if a flow started towards Hudson Bay, Lake Agassiz would disappear. It was also determined that Lake Agassiz could have only existed when there was no outflow from Hudson Bay, for instance when ice bed closed the pathways.

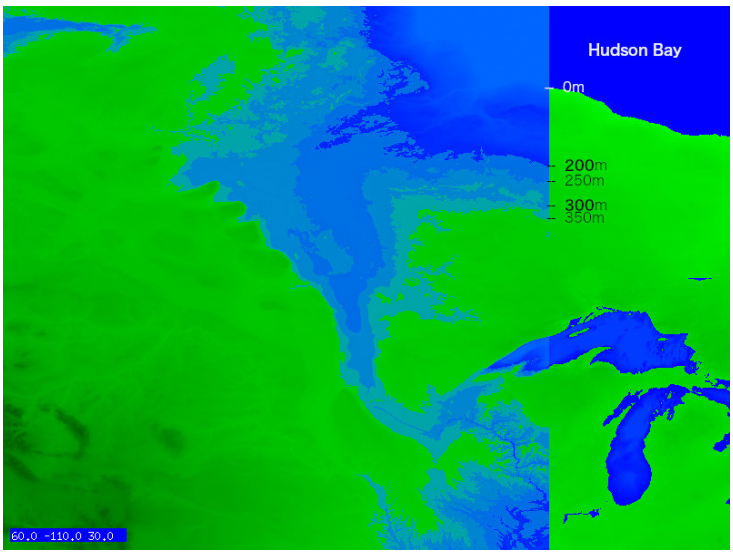


Fig. 1. Altitude of water level 200 m, 250 m, 300 m, 350 m

The surface of Lake Agassiz was set to the altitude 300 m, range up to N58° and E-94°. Proprietary software was used to calculate its area and water volume in order to compare it with other water regions.

The result showed that the water volume of Lake Agassiz was 3.9% that of the Black Sea (Fig. 4). Even if all of the water from Lake Agassiz had flowed out to Hudson Bay, it would only account for 17.2% of the water volume in Hudson Bay. The water volume was too small to bring about climate change on a global scale.

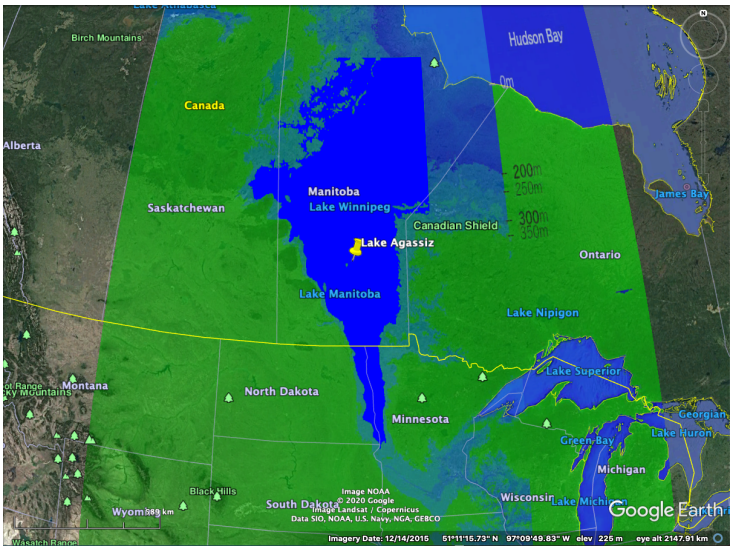


Fig. 2. Range of Lake Agassiz

	Area (km2)	Area comparison	Water volume (km3)	Comparison water volume
Lake Agassiz	381,000	1.000	21,100	1.000
Great Lakes	245,730	1.550	22,467	0.939
Black Sea	436,402	0.873	547,000	0.039
Hudson Bay	1,230,000	0.310	123,000	0.172

Fig. 4 Comparison table vs. Lake Agassiz (Note: The water volume of Hudson Bay was derived from the area multiplied by the average water depth of 100 m.)

There is a theory that Lake Agassiz caused a flood and this water flowed out to the Arctic Ocean, and traces of this event have been found[1]. However, at the water level at an altitude of 350 m (Fig.1), it did not have a northerly waterway leading to the Arctic Ocean. Therefore, the water surface at altitude 400 m was also recreated (Fig. 3).

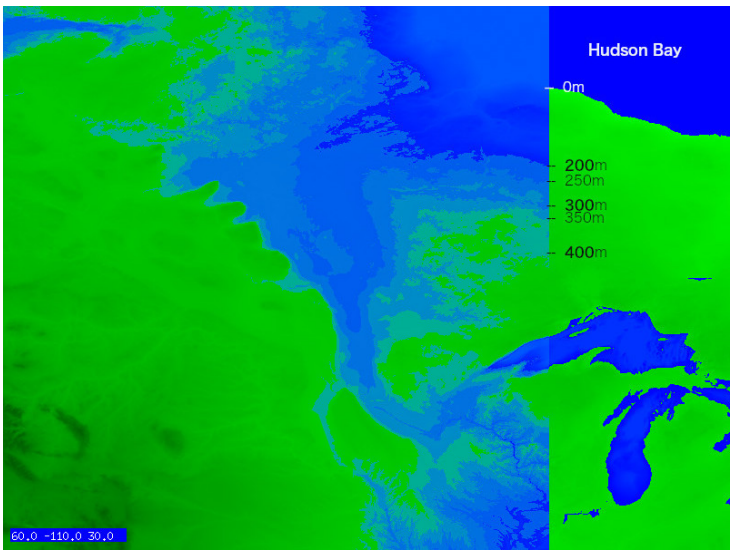


Fig. 3. Water level at altitude of 400 m.

As a result, it was determined that there were no waterways leading northwards even with the water level at altitude 400 m. At this point, the south side had an outflow waterway with a height of 100 m and a width of 100 km. If the southern side was closed by ice sheet, a water level rise of over 100 m is plausible. However, as the ice sheet was melting around Lake Agassiz, it is not

plausible that the ice sheet remained directly south of that location to block the waterway. Therefore, a lake level rise of over 100 m where outflows to the Arctic Ocean started to occur is not plausible under normal conditions.

The south side of Lake Agassiz was ground with higher altitude. Thus it would have been impossible for the ground to collapse there, and it would not have given in. Similarly, the northern and western sides also had higher ground. Thus collapse would not have been possible there either. If it had collapsed toward the direction of Hudson Bay, the water would not have flowed to the north or south, and Lake Agassiz would disappear. Therefore, the first collapse, which is thought to have occurred circa 13,000 BP, did not flow out towards Hudson Bay. In other words, Lake Agassiz was a collection of water in vast lowland. Thus continual outflows of water is plausible, but not a collapse that would have caused a flood.

(3) Discussion 1　It could be possible that a collapse of Lake Agassiz that could have caused a flood may have occurred due to factors not yet considered.

If there is a trace of flooding in Lake Agassiz, this indicates that there was a massive lake level rise. However, in order for the level of Lake Agassiz to rise, there would have to have been an inflow of water that exceeded outflow volume from the south, and this inflow would have to have happened over an extremely short period of time. This phenomenon would not be explainable just by inflow of water from melting ice sheets. The flood theories thus far may have overlooked a major factor.

(4) Result 2　A land formation that appears to be a large-scale erosion was found near Lake Agassiz.

From the NOAA land formation data mentioned above, a map that emphasizes the ground slope in the North American Continent was created (Fig. 5). From this, a land formation that appears to be a large-scale erosion was found near Lake Agassiz (Fig. 6).

It is thought that the land formation was due to an erosion of Lake Winnipeg and four small mountains (= 4 Hills) to its west, and this erosion state can be explained by a hypothesis that a massive inflow of water occurred from the direction of Hudson Bay (Fig. 7 blue arrows: flow of water, yellow: eroded area).

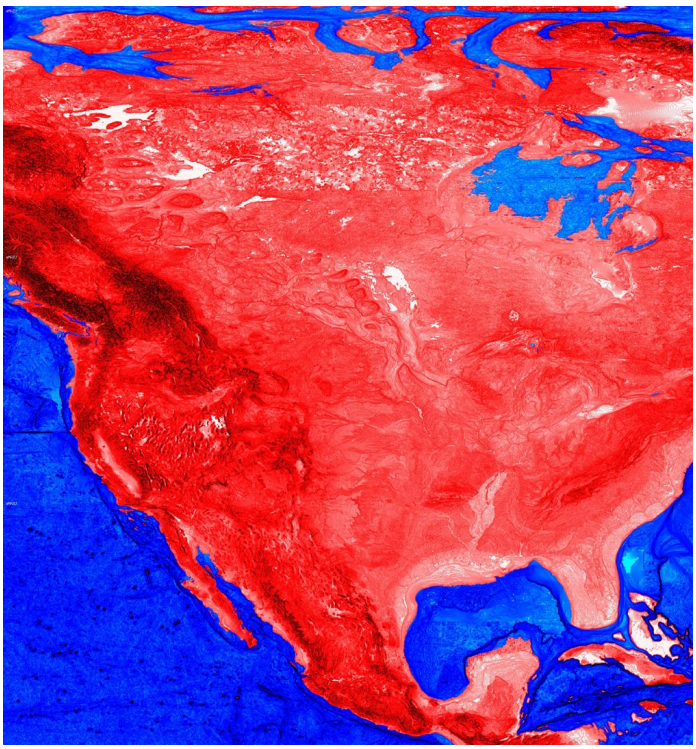


Fig. 5. Slope diagram of North America (Sea level -120m)

Fig. 5. original.png (http://www.pipi.jp/~exa/kodai/agassiz/NorthAmerica_ncline-map.png)

Fig. 6. original.png (http://www.pipi.jp/~exa/kodai/agassiz/Agassiz_ncline-map.png)

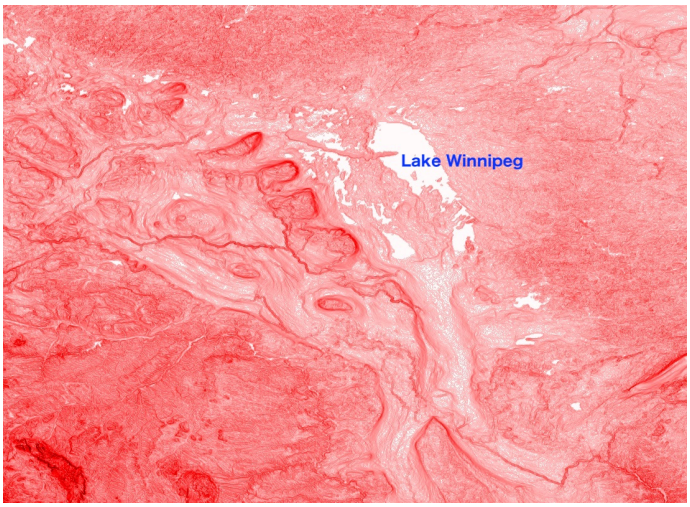


Fig. 6. Slope diagram near Lake Agassiz

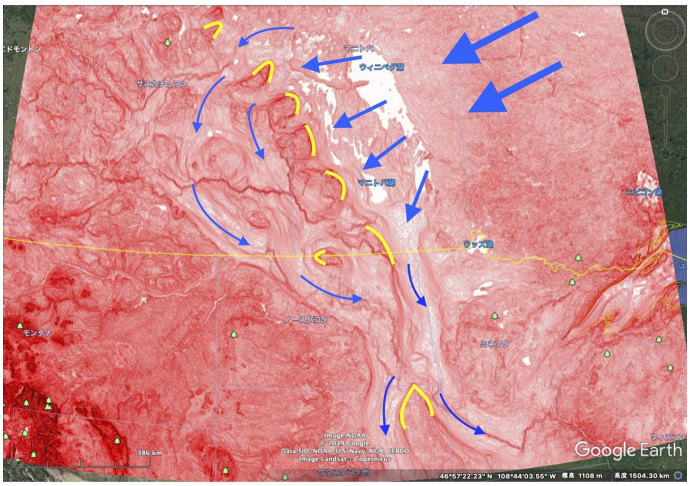


Fig. 7. Eroded area and anticipated water flow

(5) Discussion 2　There is a high probability that a Mega Ice Lake had formed above Hudson Bay.

The height of the ice sheet varies largely according to the amount of snow and the land formation. Hudson Bay is surrounded by mountains of approx. altitude 300 m. Thus, its difference in altitude with the sea floor of the Hudson Bay was approx. 500 m (Fig. 8).

Moreover, seawater does not freeze easily, and ice sheets do not form readily. Furthermore, ice melts in the summer time, and the melted water flows out to the Atlantic Ocean.

Therefore, ice sheet growth was slowed over Hudson Bay, and it is thought that the ice sheet above Hudson Bay was concave over a wide area (Fig. 9).

There is a high probability that large volume of water that had melted from the ice sheet was collected in this indentation.

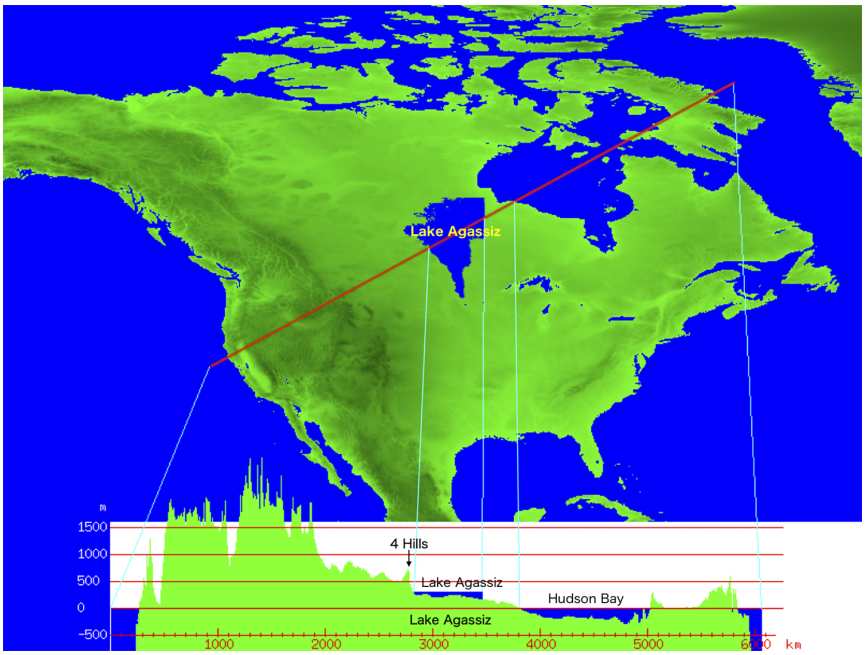


Fig. 8. Section View of the North American Continent

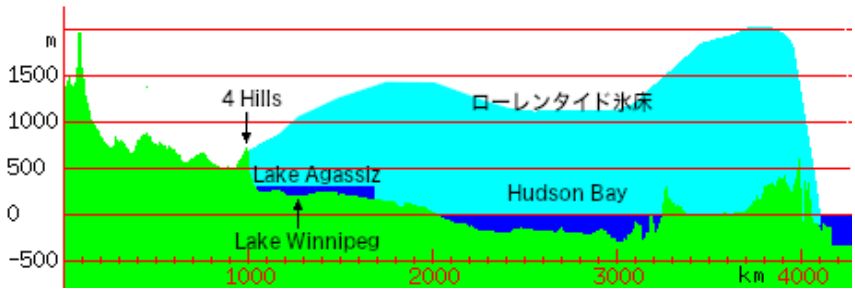


Fig. 9. Section View of the North American Continent and the Laurentide Ice Sheet (conceptual illustration)

(6) Discussion 3 The mechanism of collapse circa 13,000 BP is thought to be a massive collapse from the lower areas of the ice sheet.

If water from melting ice sheets, caused by the rising temperatures, collected in the indentation (Fig. 10), water had the characteristic of having its heaviest relative weight at 4°C. Thus the water temperature at the bottom of the ice lake would have always remained 4°C, and the ice sheet would have melted from the bottom (Fig. 11).

The ice sheet continued to melt, and the water rose to the level closer to the top area (Fig. 12). Eventually, the ice sheet, being ice, floated due to its buoyancy. As a result, it destroyed the ice sheet from near Lake Agassiz, 1,000 km away from the ice lake, and collapsed explosively (Fig. 13).

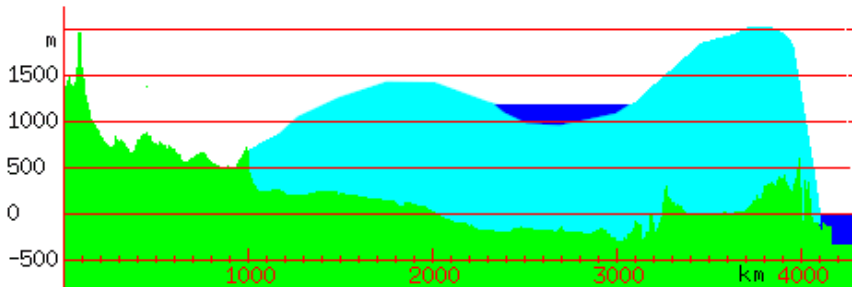


Fig. 10.

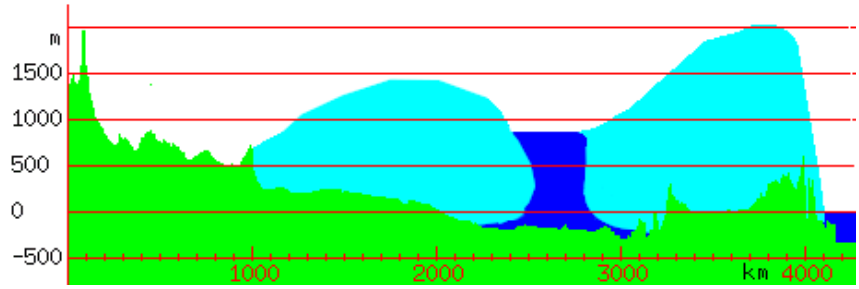


Fig. 11.

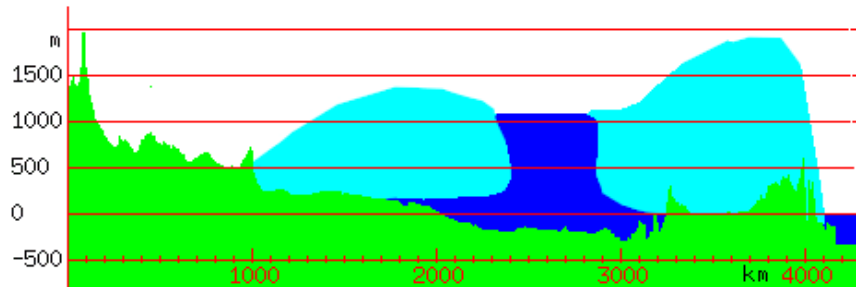


Fig. 12

.

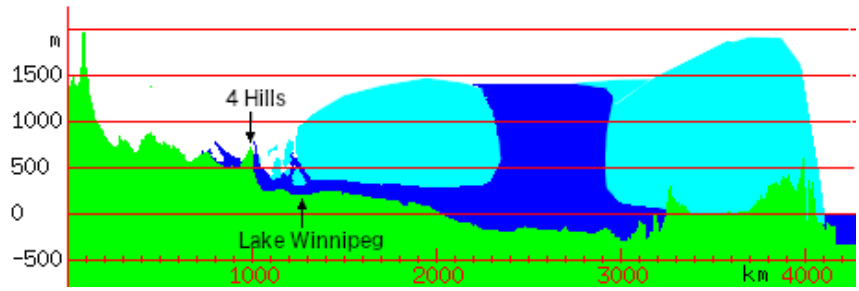


Fig. 13.

(Reference) If the water level difference is posited as 1,000 m, the outflow speed is derived from ($v=\sqrt{2gh}$) as 140 m per second (504 km / h). If the rise due to buoyancy is deemed to be 83 m, and flow width estimated from the land formation is 500 km, the flow volume can be deemed to be 5.8 km3/sec. This is an explosive collapse.

(7) Result 3 The eroded land formation matched the flood simulation.

If the simulation is run from the model in (Discussion 3), the eroded area (Fig. 6.) and the flooded region when water level difference was over 2,000m. (Note. However, the simulation software is proprietary, and there is no guarantee of accuracy.)

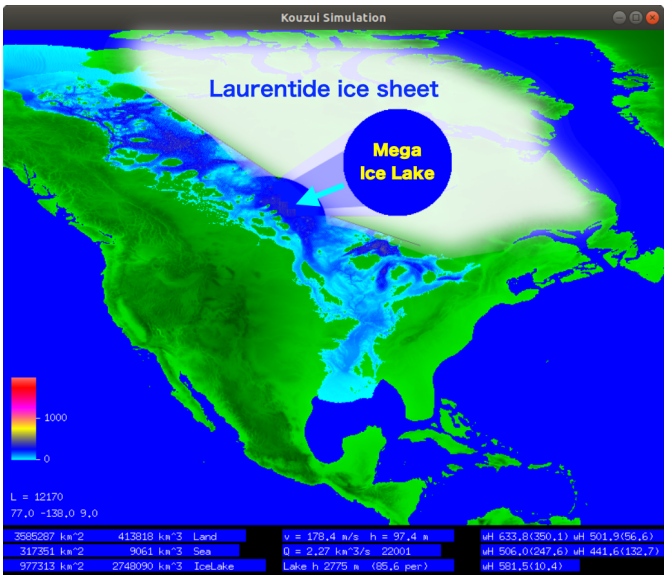


Fig. 14. Simulation example of Flood from Lake Agassiz

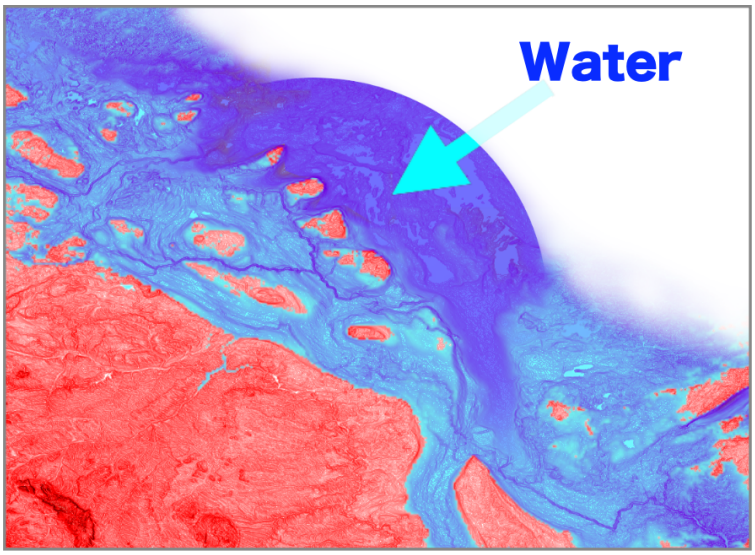


Fig. 15. Composite diagram of the slope and flooded region (Lake surface altitude 3,250 m).

(8) Result 4 The water volume of the mega ice lake matched the sudden rise in sea levels circa 8,200 BP.

The mega ice lake connected to Lake Agassiz had a maximum lake surface altitude of 300 m, a maximum area of 2.76 million km2 and a water volume of 650,000 km . If this lake collapsed toward the Atlantic Ocean and flowed out to sea level (-20m) at 8,200 BP, the sea level would have risen about 1.6 m. This result matches the theory that the sea level rose by about 0.8 to 2.2 m around 8,200 BP[2].

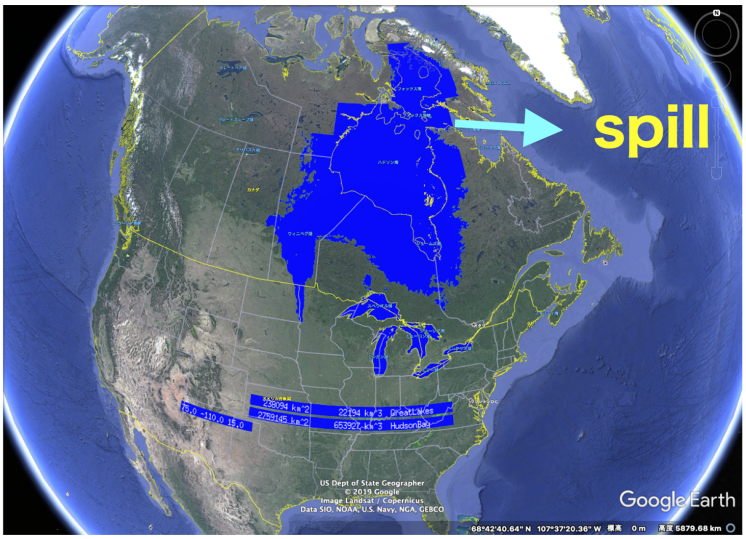


Fig. 16. The ice lake at its maximum range

(9) Summary

The collapse of a mega ice lake, calculated from a collapse model, indicates the possibility of an outflow about the volume of the Black Sea over a mere half day. Also, the water temperature was close to 0°C This explosive major collapse that would have been observable from the outer space would have changed land formations, cooled the land, atmosphere and ocean, and impacted the global climate.

Acknowledgements

・NOAA(National Oceanic and Atmospheric Administration)

・Linux, Ubuntu, GNU, GCC, GIMP

・Wikipedia　アガシー湖、Lake Agassiz、五大湖、ハドソン湾、黒海、メキシコ湾、など

・Google Earth, Apple Pages, etc.

We/The authors thank Crimson Interactive Pvt. Ltd. (Ulatus) – www.ulatus.jp for their assistance in manuscript translation and editing.

[1]“Identification of Younger Dryas outburst flood path from Lake Agassiz to the Arctic Ocean” Julian B. Murton (https://www.nature.com/articles/nature08954 (https://www.nature.com/articles/nature08954))

[2]”Synchronizing a sea-level jump, final Lake Agassiz drainage, and abrupt cooling 8200 years ago” Yong-XiangLi (https://www.sciencedirect.com/science/article/pii/S0012821X11003177 (https://www.sciencedirect.com/science/article/pii/S0012821X11003177))

(Note: If you look closely at Figure 5, the terrain differs greatly only between 60 and 67 degrees north latitude. ETOPO1 has "Ice" that shows the height of ice sheets and "Bed" that shows the ground. I used to use Ice. So I compared it with Bed, but both were the same. It seems to be data containing snow and ice between the latitudes of 60 to 67 degrees north, but this cannot be judged alone. If you have NOAA personnel, please check it out.)

Appendix

Simulation Movie 1

[VIDEO] https://www.youtube.com/embed/gqu2HAABIpY?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0

Simulation Movie 2

[VIDEO] https://www.youtube.com/embed/p33UHGiVMOc?feature=oembed&fs=1&modestbranding=1&rel=0&showinfo=0