ARCTIC CHANGE 2014
8-12 December - Shaw Centre - Ottawa, Canada

Deep crater in Central Yamal, West Siberia, Russia as a new permafrost feature in response to local climate fluctuations

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As new features like this have been reported recently in a number of mass-media publications, the processes leading to their formation may already be underway elsewhere in the region, making the study of their origin, and predicting such an activity an urgent task.

The history of study

On July16 – The first reconnaissance (several hours of study, 5 people out of which only 1 permafrost researcher and occasionally one archeologist, others being journalists and rescue man). Research equipment consisted of gas analyzer, active layer probe, radiometer, portable video recorder and a rope. Results published in the Popular science magazine "KholodOK", pdf available.

On August 25 – The second reconnaissance (again several hours, about 12 people, including one geologist – gas expert with gas analyzer, one permafrost scientist, journalists, alpinists who tried to get into the crater but had to stop near the rim for security reasons. Couple popular science papers published by Vasily Bogoyavlensky. I have no copies.

On early October, for few days geophysicists worked with various electric methods. Very exciting results published in popular science magazine "Science first hand". Pdf can be downloaded from http://sciencefirsthand.ru/c59_01_03.shtml.

On November 8-9 – Several permafrost researchers, geophysicists and alpinists worked for 2 days inside the crater for the first time. They made measurements and took samples from the walls and bottom. Still under processing.

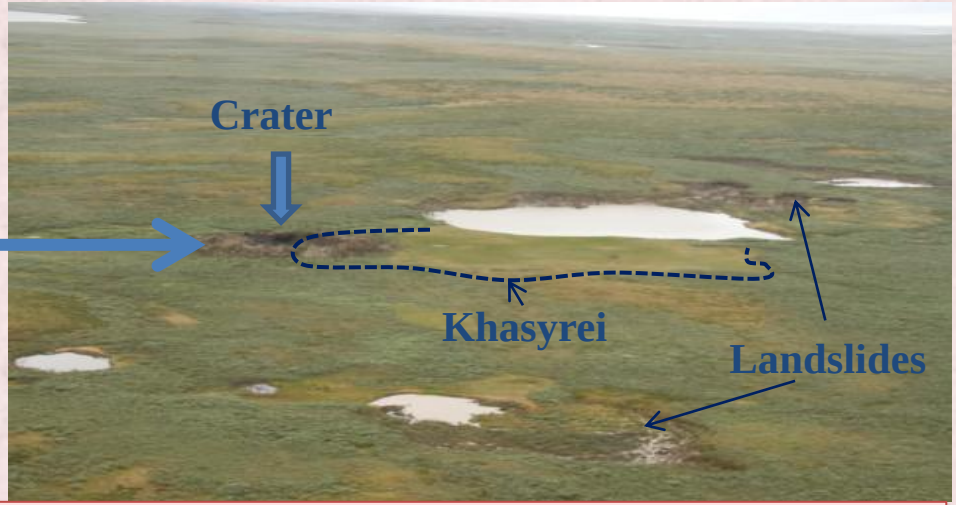
This presentation reports results of the first two recons. The later data is still in a processing and interpreting status.

The main objective of the reconnaissance was to outline the range of possible hypotheses of the crater's formation, to exclude impossible and improbable versions of its development.

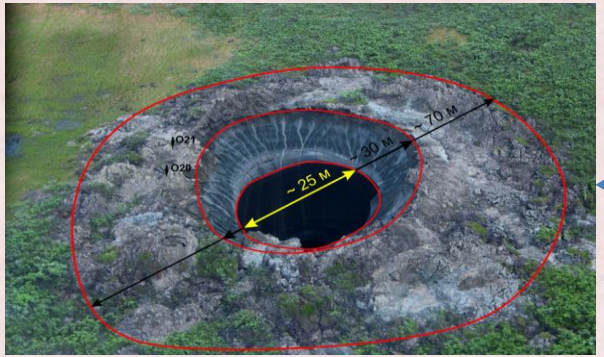
Our field study included size measurements and photo- video-documentation of the feature and the surrounding environment. This was all we had to make an expert judgment.

Reconnaissance results

To the right is the floodplain of Mordy-Yakha river, to the left fluvial-marine and coastal-marine Late Pleistocene Plains. In 4 km westward you can see the pipeline.



The crater is surrounded by rolling hills with gentle slopes, poorly dissected and thus poorly drained. Slopes are covered by dense willow shrub thickets. Note few small lakes with landslides. The bigger one closest to the crater is half-drained and crater occupies the corner of the drained part (Khasyrei).



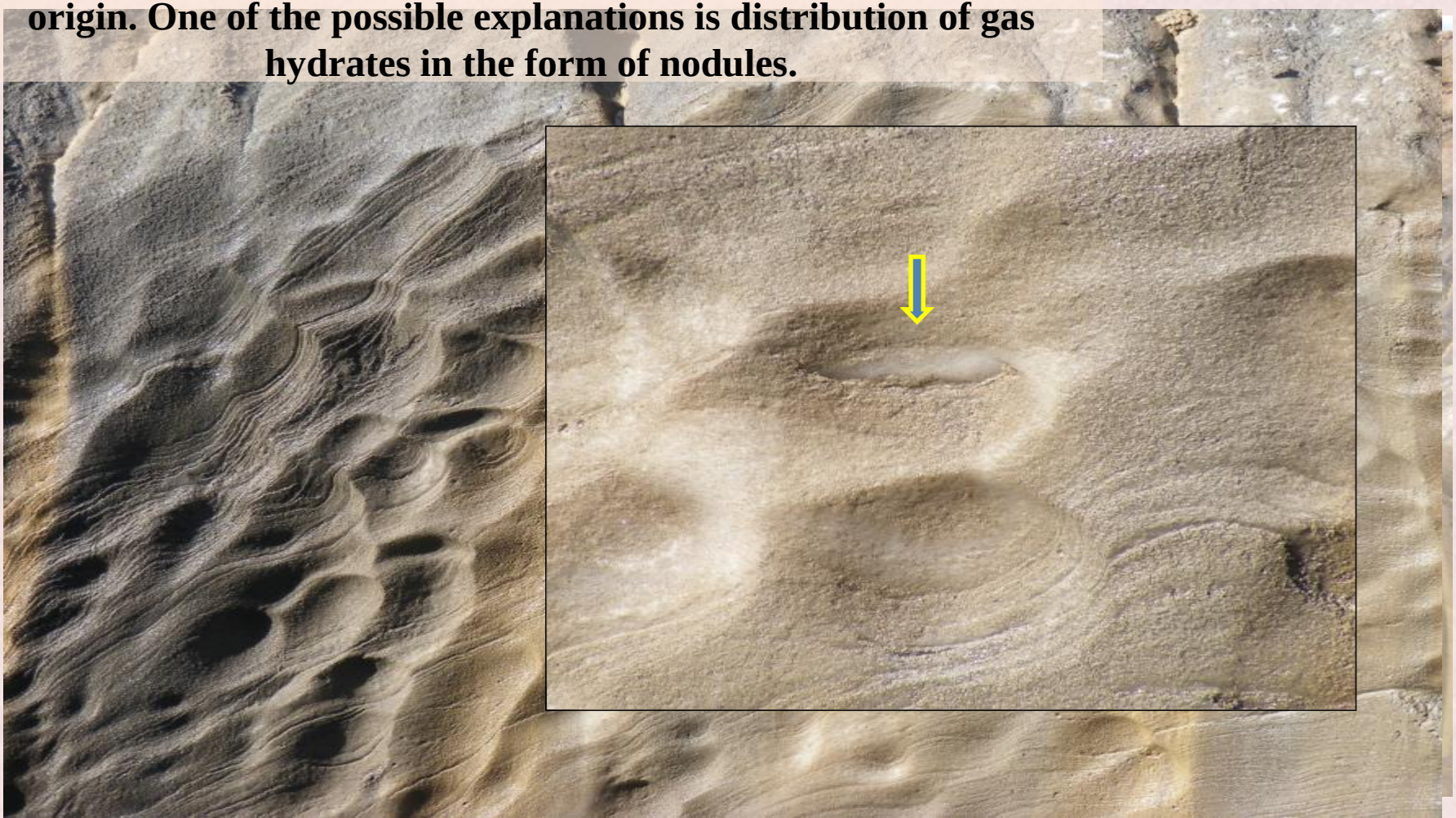
Reconnaissance results

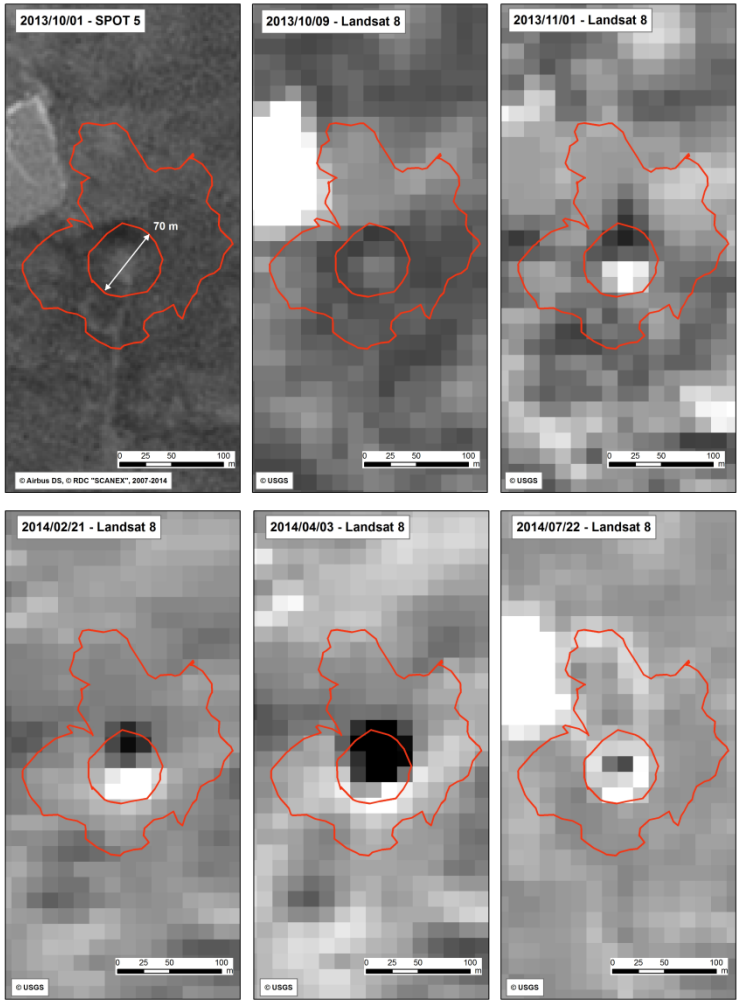
The upper part of the geological section within the crater consists of thinly stratified silty deposits highly icy, (left photo from July16). In August after the section was well washed out, it was noted that this horizon contains more than 50% of ice, and layers are oriented almost vertically and parallel to the crater walls. This can be explained by deformation during the ice intrusion to form pingo.

Reconnaissance results

The stratified sediments are underlain by almost pure stratified ice with thin silt inclusions of nearly vertical orientation of the layers. Some lenses of bubbly ice are found in the section. This stratified ice horizon is separated from the upper stratified silt by a relatively well developed layer of bubbly ice.

There is a zone with regularly distributed notches of unknown origin. One of the possible explanations is distribution of gas hydrates in the form of nodules.

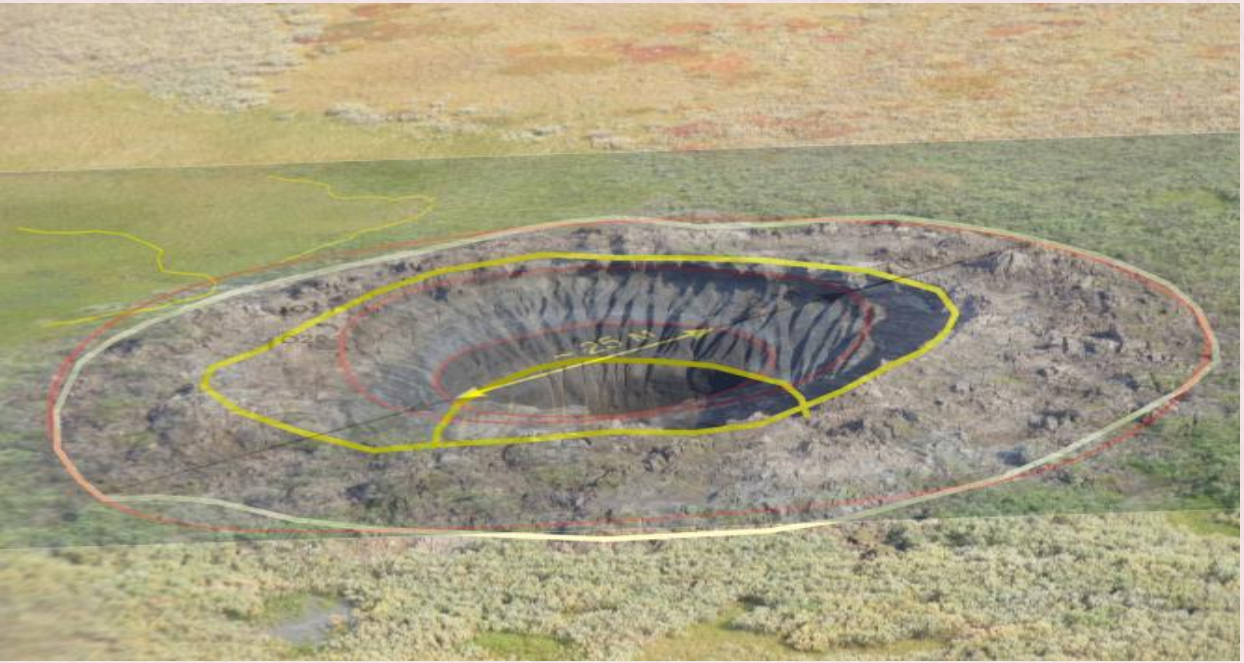




Time series of SPOT 5 and Landsat 8 images. Red lines outline the parapet (inner circle) and area of ground blocks scattering (outer line). Based on the remote sensing data, we assume that the crater was formed within the time range from 2013/10/09 to 2013/11/01.

A. Kizyakov, A. Sonushkin, M. Leibman, M. Zimin, A. Khomutov. 2015. Relief morphology of the gas-emission crater in Central Yamal using satellite very high resolution stereo pairs. *EARTH CRYOSPHERE, XVIIII(2), in press.*

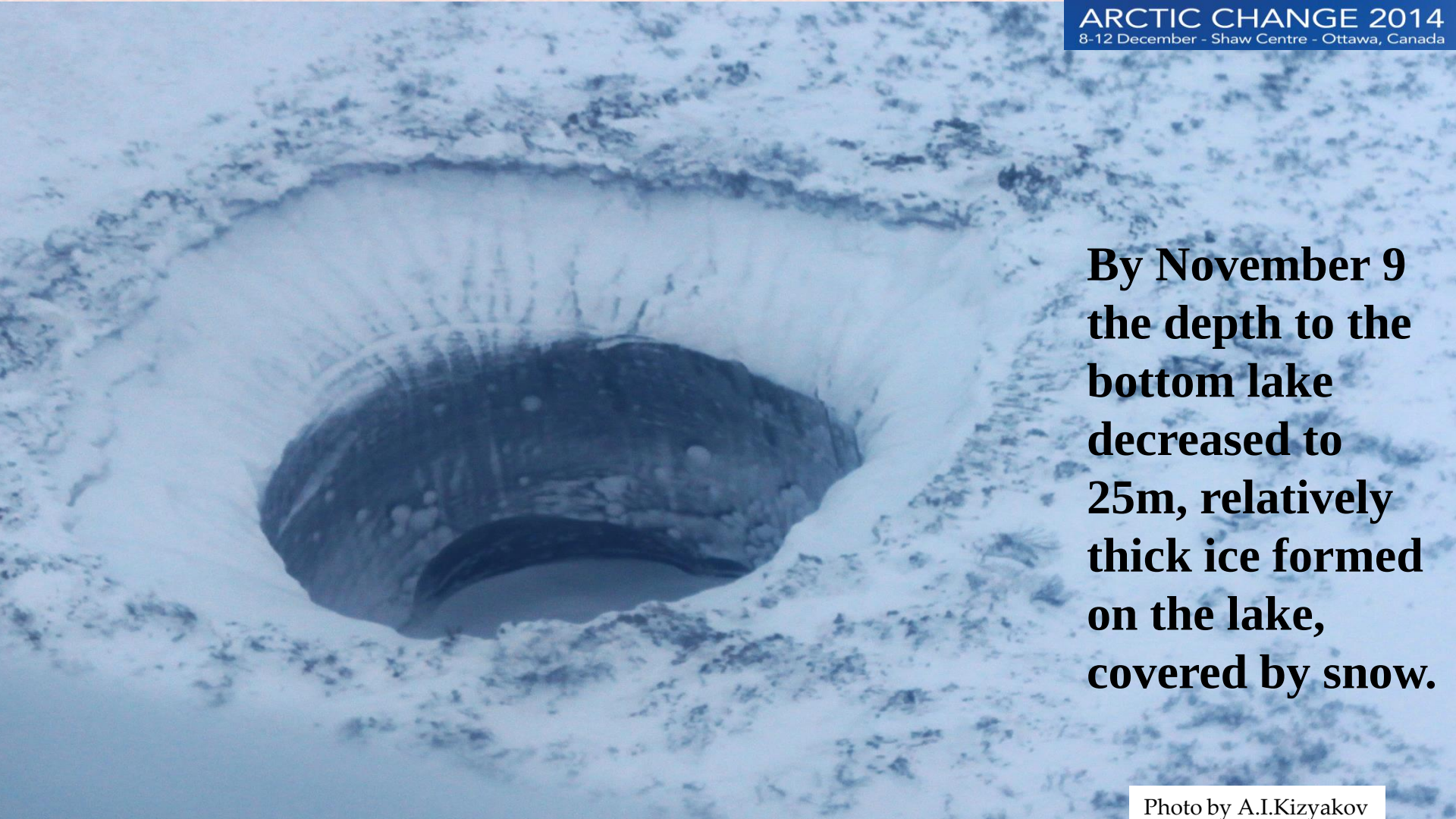
Crater dynamics



In 6 weeks from July16 to August 25:

- Inner diameter increased from 20-25 to 30 m, outer from 35 to 45 m.
- Depth to the bottom lake decreased from more than 50 m to 35 m.

M Leibman, A Kizyakov, A Plehanov, I Streletskaya **2014. New permafrost feature: deep crater in Central Yamal, West Siberia, Russia as a response to local climate fluctuations.** Geography, Environment, Sustainability Magazine, 4.



By November 9 the depth to the bottom lake decreased to 25m, relatively thick ice formed on the lake, covered by snow.

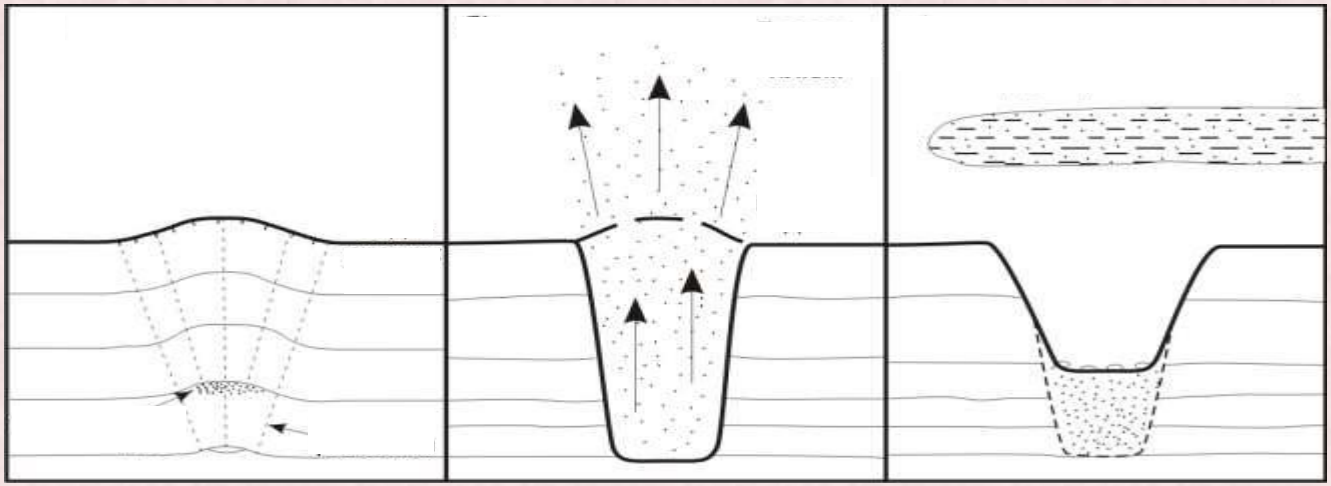
Photo by A.I.Kizyakov

Impossible and improbable hypotheses

- The Yamal crater, is now known to be one of 3 or 4 which appeared within the last 2 years. Their existence is beyond doubt.
- The crater is surrounded by a parapet, thus is resulting from expulsion of ice and rocks from beneath to the surface and should not be treated as a “sinkhole”, “karst” or “collapse”.
- As water is accumulating at the bottom, there is no pathway through into the interior. More over, it was established that filling of the crater, pieces of sod and silt, and melt water, had partly frozen from the bottom up, so there is no non-frozen channel in this place. Thus, it is hard to assume that deep-seated gas deposits penetrated through permafrost to produce the pressure needed to “open the bottle”.
- There are no traces of human impact around the crater. The phenomenon is natural.
- There are no traces of radiation or high temperature, thus it is hard to suggest the impact of extraterrestrial origin like meteorite, as well as gas explosion.

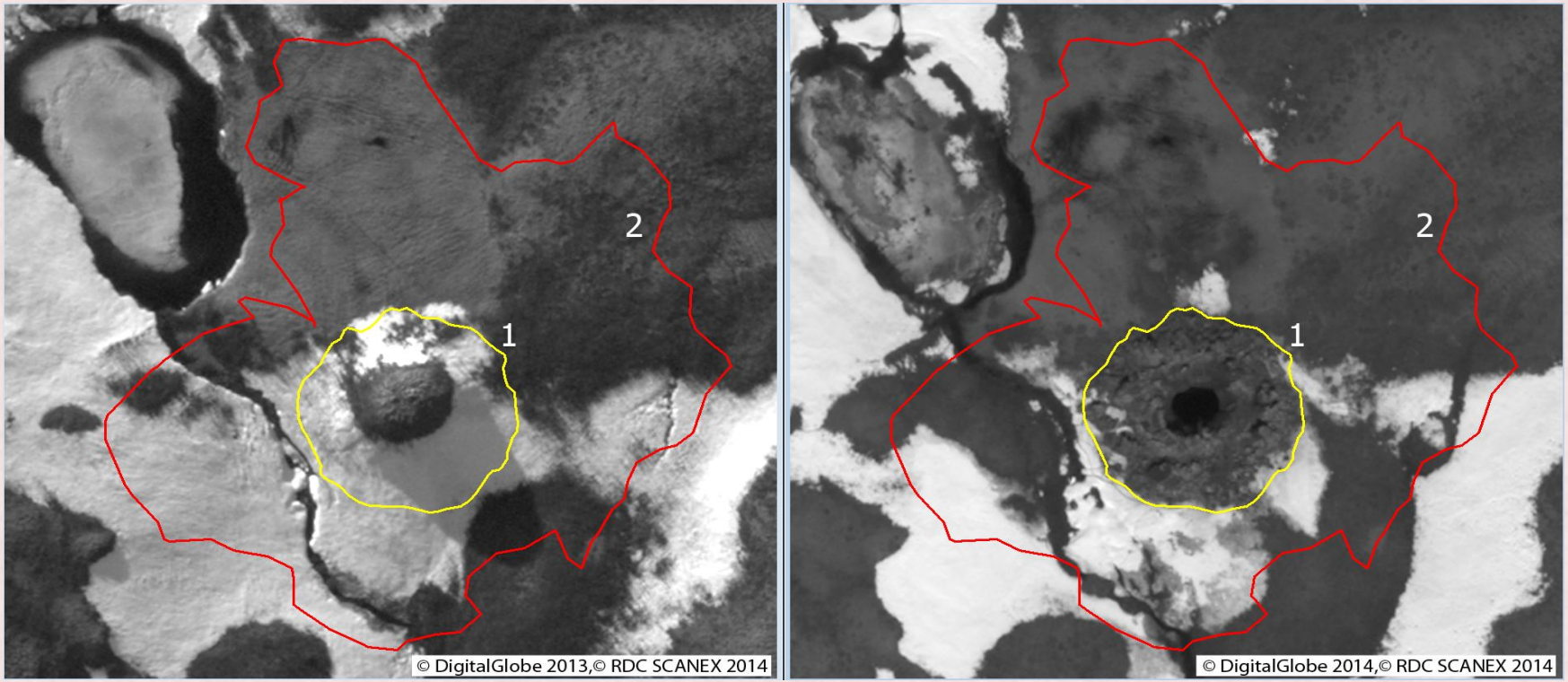
So what are the probable hypothesis?

No landform like the crater in Central Yamal discussed in this presentation has been reported previously. Yet similar forms: seabed pockmarks, have been known and discussed since the 1970's.



(after Judd, Hovland, 2007)

Deep roundish lakes are characteristic of Central Yamal



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Conclusion

Excluding impossible and improbable versions of the crater's development, the authors conclude that the origin of this crater can be attributed to the air temperature warming trend along with the extreme of 2012. The increased ground temperature and amount of unfrozen water in the permafrost, expanding of cryopegs, formation of a pingo-like mound and its outburst due to high pressure produced by gas hydrate decomposition within permafrost are the main controls. Similar temperature anomalies may increase in number in the future decades, presenting risks for human activities in the region.

This conclusion is supported by recent studies of gas-hydrate behavior in the upper permafrost as well as by subsea processes in gas-bearing provinces where analogue mechanism is known to produce pockmarks – subsea depressions.

Intensive thawing of the upper part of the crater results in the retreat of its walls, decrease of the depth, and finally in the formation of the small deep lake. It is highly probable that many deep and roundish Yamal lakes considered before as purely thermokarst lakes are rather of the same gas-emission origin.

Thank you for your attention