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New York State Department of Environmental Conservation
Bureau of Resource Management & Development
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Attention: Mr. Matthew Podniesinski
Director, Bureau of Resource Development
and Reclamation

Subject: Scour and Frontenac Point Anomalies
Cayuga Mine, Cargill Deicing Technology, Inc.
Seneca and Tompkins Counties, New York

Gentlemen:

At the request of the New York State Department of Environmental Conservation (NYSDEC), John T. Boyd Company (BOYD) has summarized the progress of research and engineering design in reference to overburden anomalies in the northern reserves of the Cayuga Mine of Cargill Deicing Technology.

BOYD became aware of what was then called the “disturbed salt area” and now known as the Frontenac Point Anomaly (FPA) during meetings with the staff at the Cayuga Mine who expressed a concern about mining north. During one of the initial meetings David Plumeau forwarded a report by Stearns & Wheler and Syracuse University¹ which reported on a seismic study of Cayuga Lake. This paper is the first to present a seismic survey of the lake and noted that the deepest glacial scour of the bed rock occurred one third of the way up the lake from Ithaca where the bedrock is eroded to 1,175 ft below lake level. They note that the scouring is likely controlled by the Onondaga Limestone.

¹ Hinchley, Edward J., H.T. Mullins, and A. Hine, 1991, Seismic Stratigraphy and Depositional History of Cayuga Lake, Geologic Society of America Special Paper - The Origin and Evolution of the New York Finger Lakes.

After the review of this paper, BOYD noted that the FPA is located at the intersection of two defined linears that corresponds to joint swarms identified by Engelder and Geiser²; joint swarm Ia that strikes north-south and joint swarm II that strikes east-west and parallels the regional folding. The lake bottom generally parallels joint swarm Ib. This location is just north of the kimberlite dykes swarm (Ithaca Kimberlites³) that parallels joint swarm Ia and may be a contributing factor to poor mining conditions in the southern extent of the Cayuga Mine.

In 1998, BOYD⁴ wrote a letter to the NYSDEC about the FPA and both the NYSDEC and BOYD became mindful of this disturbed zone. Concerns focused on the global stability of the mine, the potential inundation of the mine thus affecting the safety of the miners, and the potential of adversely affecting Cayuga Lake. Cargill agreed to avoid the disturbed area until further study was completed.

After further study of the FPA, BOYD⁵ reported in 2002 to NYSDEC that the disturbed area appeared to be a graben-like structure with a vertical displacement of approximately 100 ft and that further investigations are needed before mining could proceed into this zone.

NYSDEC Response

The NYSDEC added the following conditions to the 2003 mine permit:

- Special Conditions 18 – Cargill shall conduct further investigations of the disturbed salt zone, identified by seismic survey and shown on No.6 Salt structure contours (top of salt), which may exist near the west shore of the lake in the northern extended mineral lease area. Mine projections show that present plans are to extract this area sometime between 2016 and 2020. Further investigation of this disturbance needs to be completed and submitted to the Department for review before mining proceeds in this area.
- Special Conditions 19 – Cargill shall conduct further investigations and report on the adequacy of the thin rock overburden at the northern extent of the mineral lease area

² Engelder, Terry and Peter Geiser, 1980, On the use of regional joint sets as trajectories of paleostress fields during the development of the Appalachian Plateau, New York, Journal of Geophysical Research, Volume 85, Issue B11, Pages 6319–6341, 10 November.

³ Mahlburg Kay, Suzanne, William T. Snedden, Brayton P. Foster, and Robert W. Kay, 1983, Upper Mantle and Crustal Fragments in the Ithaca Kimberlites, The Journal of Geology, Volume 91, Number 3, May.

⁴ Scovazzo, Vincent A., 1998, Meeting of December 19, 1997, Cayuga Mine, Cargill Salt, letter to C. B. McGranahan, New York State Department of Environmental Conservation, John T Boyd Company project number 2499.2, January 5.

⁵ Scovazzo, Vincent A. and Russell P. Moran, 2002, Review of the Mined Land Use Plan, Cayuga Mine, Cargill, Inc., prepared for New York Department of Environmental Conservation, John T. Boyd Company Report No. 2499.4, February.

where the solid rock overburden becomes thinner where the glacial till and lake sediment thickens and lake depth increases and where mining is proposed for this area after 2030. This condition must be thoroughly analyzed for stability by Cargill and reviewed by the Department before mining proceeds in this area.

These conditions are repeated in the presently enforced permit as 9.a. and 9.b.

In 2009, Boyd / PetroSearch⁶ further defined the lake scour and identified five areas of deep gouge that were labeled as anomalies A through E within the continuous scour. One of these anomalies (Anomaly E) had already been undermined without affecting the mine's global stability. Since the anomalies are located in the northern mine reserve, Anomalies A through D would then require additional study before mining below these anomalies would be permitted. If these studies determined that mining will not adversely affect global stability or adversely affect Cayuga Lake, it would follow that mining between these anomalies will also have no adverse effects.

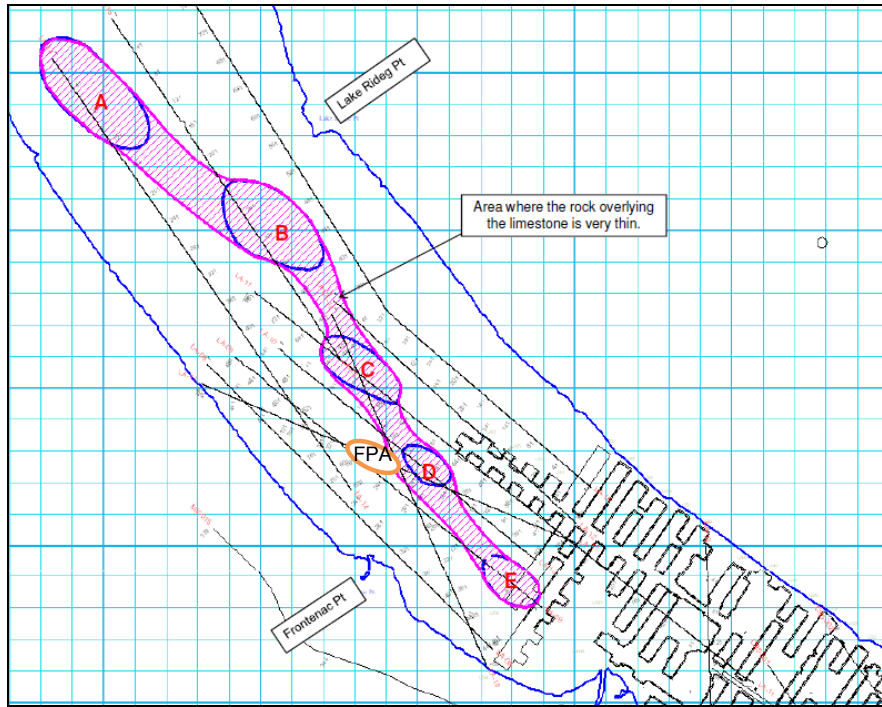
On December 24, 2010, NYSDEC⁷ affirmed and agreed that Cargill's suggested stand-off of 1,000 ft around the FPA, where no mining will be permitted, is reasonable. NYSDEC noted that if further consideration is to be given to this distance, additional information will need to be submitted to the Department for review and approval.

On March 13, 2015, BOYD and the NYSDEC recognized that mining options at the Cayuga Mine were becoming limited and would cause Cargill to develop northward and possibly require mining under the scour anomalies (A through E). It was decided that

⁶ Willott, Richard, 2010, Geophysical Progress Report, Analysis of the Frontenac Point Anomaly, Cayuga Mine, for Cargill Salt Division, Boyd / PetroSearch Project #20101017, August 3, 2010.

⁷ Army, Steven M., 2010, Cayuga Salt Mine MF#70052, New York State Department of Environmental Conservation letter to Russell S. Givens, Cayuga Mine, December 24.

BOYD and the NYSDEC would emphasize in discussions with Cargill that investigations of the FPA and all scour anomalies should quickly move forward.



Scour Anomalies A through E as Identified by Willott⁶, the FPA Placed on Figure by BOYD

Further Seismic Studies by Cargill

In 1994, Cargill purchased a 1984 commercially available seismic survey from GeoData Corporation to further understand the geologic setting of the Cayuga Mine. GeoData reprocess the data and the interpretation was completed by Sear-Brown Group. In 1995, Cargill hired Bay Geophysical to complete extensive seismic surveys of the southern half of the Cayuga Lake. These data were processed by GeoData and interpreted by Sear-Brown Group. The results of the 1995 survey were considered good to poor but adequate to identify the mine location. In 1996, Cargill hired Duncan Exploration, Inc. to complete a land based survey. These data were processed by GeoData and interpreted by Sear-Brown Group. These studies showed the FPA and a lake scour.

Two additional lake seismic studies were completed in 2009 and 2016 to define the depth, location, and geology of the anomalies. In addition, the 1995 and 1997 data were reanalyzed because of advancement in software. In 2009, Cargill hired Walker Marine Seismic for a lake seismic survey; these data were processed by CGG Veritas and interpreted by Boyd / PetroSearch and RESPEC, which further defined possible limestone fracturing and the extent of the FPA.

In 2016, Bay Geophysical was again hired to complete a cross lake survey; these data were processed by Sterling Seismic Services and interpreted by Corona Consulting and RESPEC, which further defined the anomalies.

These seismic studies have been evaluated by Dr. William Goodman (RESPEC and Sear-Brown), John Clark (Corona Consulting), Richard Willott (Boyd / PetroSearch), and John Schneider (RESPEC). It was reported⁸ that this group believes that the anomalies represent erosion of bed rock that extends into the Helderberg limestone. The group could not discount faulting beneath the anomalies and confirmed that the FPA represents a fracture in the limestones but there was no convincing evidence of lower limestones collapse due to salt solutioning.

Boyd / PetroSearch reported on the 2009 study defining the five scour anomalies (A through E) noting that the C and D anomalies show a "... maximum disturbance, where the upper salts may be leached, and the overlying carbonates broken and discontinuous."

Cargill Engineering Studies of the Anomalies

Cargill, in their letter to BOYD⁹ notes. "...work has begun on re-evaluating the geologic anomaly previously identified on seismic lines north of Frontenac Point. At this time, development mining has stopped in the NW-2 mains..."

In 2007, RESPEC addressed the FPA¹⁰ calling it a "suspected geological structure" and this anomaly was identified by a seismic study located approximately 2,400 ft north of Frontenac Point. Based on seismic studies, RESPEC suggested that the anomaly is a deep penetrating, nearly vertical, east-west-trending fault.

Of interest to RESPEC was Seismic Line 7, located on the west side of the lake that may show that the anomaly likely penetrates the Syracuse Formation. There is a down warping of the strata on both sides of the anomaly extending up through the lower half of the glacial till and is reminiscent of a collapse due to salt-dissolution.

⁸ Plumeau, David, 2017, Memorandum, Assessment of the Feasibility of Mining Beneath the "C" Anomaly, Cargill Deicing Technology, Cayuga Mine, to Vince Scovazzo, John T. Boyd Company, October.

⁹ Plumeau, David, 2007, untitled letter to Vincent A. Scovazzo, John T. Boyd Company, February 20.

¹⁰ DeVries, Kerry L., Paul E. Nelson, Leo L. Van Sambeek, William M. Goodman, 2007, Mine Stability Assessment, Cargill Deicing Technology, Cayuga Mine, Lansing, New York, RESPEC Topical Report RSI-1913, prepared for Cargill Deicing Technology, January.

RESPEC recommended that Cargill complete a floor elevation survey of NW2 and surrounding production panels that may indicate if a fault is near and possibly represents the FPA. Also, a face-drilling program was recommended to characterize the anomaly before mining the salt below the anomaly.

RESPEC cautioned that brine may be associated with the FPA and that as the anomaly is approached, the vertical distance between the salt and the base of the groundwater-saturated rock is likely to decrease. RESPEC notes that the NW2 mains at the time were close to the valley axis where the overlying carbonates will thin to less than 130 ft and recommended that the mains be shifted to the east. This shift has been completed by Cargill.

In 2014 RESPEC¹¹ noted “Well data in the northern part of the Cayuga Lake Valley have determined that brine is present on top of and in between beds in the Salina Group. The Frontenac Point Anomaly may reflect the southern extent of water infiltration.” RESPEC opined that the planned 1,000 ft buffer around the FPA should prevent a hydraulic connection with the mine. Further, “As the mine progresses north, micro-seismic monitoring to detect anomalies and drilling in advance of the faces to detect an increase in moisture or presence of water is recommended as a precaution.”

In 2016 RESPEC¹² designed large pillars for the C Anomaly that would reduce shear in the overlying salts and reduce shear to insignificant levels in the limestones.

Mr. Petersen¹³ noted that due to the theory “... that the abnormal closure in U12, U40B and perhaps U24 could be due to hydraulic pressure within the de-stressed zone of the yield pillar panel design, it was wisely decided not to use the YPP (yield pillar panel) design to mine the northern reserves where the potential for high pressure/high volume aquiferic water in conjunction with large geological anomalies could bring water too close to the mining horizon. The concern being that the YPP design creates a low stress (destressed) zone above that panel that attracts higher pressure fluids in the rock strata, which given a geological conduit will flow into the de-stressed zone resulting in abnormal panel closure.”

¹¹ DeVries, Kerry L., William M. Goodman, and Cody A. Vining, 2014, Mine Stability Assessment, Cargill Deicing Technology, Cayuga Mine, Lansing, New York, RESPEC Topical Report RSI-2371, prepared for Cargill Deicing Technology, April.

¹² DeVries, Kerry, 2016, Large Pillar Design, RESPEC, September 15. As Large Pillar Design 9-19-16 V2.pdf last modified on September 20, 2016.

¹³ Petersen, Gary, 2016, Cayuga Mine, Thoughts on Mining the Northern Reserves, prepared for David Plumeau, Cargill Deicing Technology, RockTec Solutions, August 27.

In addressing the big pillar design of RESPEC to undermine C Anomaly, Petersen continues “The big pillar design doesn’t create a de-stressed zone above the panel, making it a much better design for potential water pressure situations.” Thus “... the potential for developing a leak is much lower ...” and “We know from experience that the big pillar design is prone to shear the roof along the roof/pillar contact out over the room and in some cases results in a rather large roof fall.”

In reference to a set of yield pillars that will result in the three entry access to the large pillar area Mr. Petersen notes “The load transfer from the YPP initially goes to the edge of the adjacent big pillar and creates a relatively high peak load along the edge of the pillar ... which can cause roof shears to develop rather quickly.”

Large roof falls at pillar edge and roof shear at the YPP – big pillar transition, as discussed by Mr. Petersen, are local events and not a factor in, or represent, global instability.

Drilling Investigation of Anomaly C

Several Investigators, including BOYD, RESPEC, and the group that evaluated the 2009 and 2016 seismic studies, had recommended drilling Anomaly C to verify assumptions and to clarify conditions. BOYD noted to Cargill that some of the questions about the anomalies could be clarified including:

- Whether or not a brine layer existed within the 4 Salt and the immediate roof.
- If water or brine exists, whether or not it is under pressure suggesting a connection to the lake or groundwater.
- Determine if a fault exists.
- Verify the thickness of the salt to show that solutioning did not occur or was minimal.
- Determine if down warping exists.

This planned drilling program was developed by Cargill and presented to NYSDEC and BOYD.

Mr. Plumeau⁸ presented the results of this drilling program to BOYD in 2017. In his words “Although the computer modeling suggests there is no risk of large pillar mining under the C anomaly, Cargill chose to do advanced drilling to verify that there was no water present at a level 260’ above the mine horizon in the footprint of the C anomaly. The drill hole was angled up into the #4 salt bed then deflected horizontally. That region is well above the expected de-stressed strata created by large pillar mining. The drill

hole and side tracks covered the length and width of the C anomaly as defined by lake seismic work.”

Before drilling commenced into the 4 Salt, the holes were shut-in and the wellhead and the casing was successfully tested to 1,500 psi and held at 1,200 psi.

After each drilling day, the drill hole was allowed to drain for about 25 to 30 minutes and then sealed. When checked in the morning, the hydraulic head would be about 75 ft (32.5 psi). At day’s end, the hole was allowed to drain for 45 minutes, and the following morning pressure rise was noted to be insignificant.

After drilling was completed, the holes were shut in (i.e., sealed) and the pressure checked every week. Mr. Plumeau noted that “There has been zero pressure increase when shut-in.” “Opening the valve at the collar results in zero discharge of gas or brine—it is a dry hole.”

“... drilling totaled over 8,000 lineal feet and has undulations and side tracks vertically up and down, and horizontally.” For long-term monitoring, Cargill plans to install micro-seismic geophones in the hole and leave it open. Cargill will place a barrel under the collar of the hole and a conductivity meter will be placed in the barrel to monitor water discharge. If water enters the barrel, the meter will alert Cargill that the hole is draining water.

The hole was developed by REI Drilling Inc.¹⁴ during March and September 2017 and “... installed one (1) multi-lateral directionally drilled borehole for exploration of the projected C Anomaly. REI drilled an exploratory borehole laterally within the 4 Salt seam to verify continuity of salt and the presence or lack of water in the formation. The borehole originated from H2 crosscut within U72 in the Number 6 Salt Bed and directionally drilled up to the 4 Salt seam. Five (5) roof tags and two (2) floor tags were drilled within the main borehole. Additionally, three (3) branches were drilled to the C Anomaly estimated extent.”

¹⁴ Schumacher, Forrest, 2017, Report of Directional Drilling for Exploration of the C Anomaly at Cargill’s Cayuga Mine, to Alex Greenblatt, Cargill Deicing Technology, REI Drilling Inc., October 16.

Drilling description:

<u>Depth (ft)</u>	<u>Diameter (inches)</u>		<u>Notes</u>
	<u>Hole</u>	<u>Casing</u>	
162	12.75	8	Centralizers, grouted
540	6.75	4	
8,494	3.8	open hole	

The total depths achieved in each branch of the drilling program were:

<u>Branch Name</u>	<u>Total Depth (ft)</u>
Main Branch	3,570
Branch #1	3,875
Branch #2	3,894
Branch #3	3,364

Drilling hole direction and hole location was maintained by a non-magnetic directional drilling motor and a DDMS survey tool that measures orientation.

“Drilling did not encounter any anomalous conditions within the 4 Salt, which was verified by monitoring drill cuttings, gamma counts from the survey tool, and measuring shut-in pressures at the wellhead.”

“The 4 Seam thickness was estimated by drilling corresponding roof and floor tags (side-tracks) at boreholes depths of 3,166 ft (roof), 3,228 ft (floor), 3,530 ft (floor), and 3,549 ft (roof). REI estimates salt thickness of 48 ft and 32 ft at depths of 3,020 ft DT and 3,370 ft DT respectively. Gamma counts ... show continuity of salt in all lateral portions of the borehole.” BOYD notes that at the nearby Borehole 18, the 4 Salt was 48 ft thick.

Conclusions

After reviewing the data presented to BOYD by Cargill, BOYD recommended that Cargill be permitted to mine under the C Anomaly using RESPEC's large pillar design, but not under the other scour anomalies or the FPA. It is BOYD's opinion that the 1,000 ft no-mining buffer should remain around the FPA and that mining under the Anomaly D and the FPA not be permitted because of the close proximity of these two anomalies. Mining under the A and B anomalies will require additional investigation specific to those anomalies and be reviewed and evaluated by BOYD and the NYSDEC before progressing.

BOYD arrived at this conclusion because the seismic surveys defined the extent of the C Anomaly, RESPEC designed a large pillar configuration to reduce stress in the 4 Salt and carbonates, and the drilling program showed:

- No brine or water was under pressure in the 4 Salt.
- Brine in the 4 Salt and its roof was not present in any significant quantities.
- Faulting was not detected.
- The 4 Salt was of expected thickness thus salt solutioning was minimal or did not occur.
- Down warping was either not present or minimal.

BOYD and the NYSDEC will monitor mining progress and the global stability under the C Anomaly by review and analysis of:

- Water/brine discharge from the C Anomaly exploration hole which may indicate if a connection develops between the 4 Salt or roof to groundwater or lake.
- Closure stations which will allow insight into opening behavior.
- Visual observation of mine conditions.
- Results from the Cayuga Mine micro-seismic monitoring system which will show activities within the overburden above the 6 Salt.

Please contact us if you require additional information or if we may be of further service.

Respectfully submitted,

JOHN T. BOYD COMPANY

By:



Vincent A. Scovazzo
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