Update on the seismic evaluation of the plans for Shaft #4 in the Cayuga Salt Mine, New York State
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Authored by

Angus Ferguson and John Warren

SaltWork Consultants Pte Ltd (ACN 068 889 127)
Kingston Park, Adelaide, South Australia 5049

www.saltworkconsultants.com

Executive Summary

There is now multiple public-domain evidence, seismic and geological, that the Onondaga Formation has been downcut by the valley floor in the area of the Cayuga mine. This thinned area of overburden between the valley floor and Syracuse Formation area is expected to be the Frontenac Point Anomaly, referred in the 2016 Annual Report. The report did not explain what the anomaly is, the exact location of the anomaly or why there is a 1000 ft exclusion zone around the anomaly. It is expected that this is an area of thinning of bedrock overlying the future planned mining area.

Full details of our seismic evaluation (public domain data only) and integration with the geology of the proposed Cargill Shaft #4, tied back to seismic information currently in the public realm, will be detailed in an upcoming Saltwork report due in mid-May 2017, authored by Angus Ferguson and John Warren.

Based on the concerns expressed in this upcoming report, and other earlier documents compiled by SaltWork Consultants Pte Lte, it is felt that an independent evaluation of the recent 2016 seismic data collected by Cargill is critical to determine the risk of future mining in the permitted northern mining reserves beneath Cayuga Lake. This should be done before permission to construct Shaft #4 is granted, and the mine operations move further north and west beneath Lake Cayuga.

Overview

This short note summarises current understanding in a project underway in Saltwork Consultants Pte Ltd. This study is integrating all existing public domain seismic and geological data in the region of the Cargill Cayuga Salt Mine and the proposed Shaft #4. Public domain information made available to us recently, including detail from annual reports, reviews and maps have further emphasised our concerns, based on what we are now seeing in the seismic evaluation study currently underway in SaltWorks, and expressed earlier in the Warren (2016a, b) reports evaluating the geological setting of Cargill Shaft #4.

The primary areas of concern are:

1. The expansion of the mine to the north and west will likely encounter complex structures and possible fractures that connect the aquifer in the Onondaga/Oriskany Formation to the Syracuse Formation.

2. A back-reaming plan for the construction of Shaft#4 carries a high risk of connecting an active aquifer in Onondaga/Oriskany Formation level to the mine workings in Syracuse Formation and is therefore not recommended without better independent quantification of this risk (additional seismic and geologic analysis is required).

3. Further seismic data are needed in the public domain to confirm the extent of the anticlines and possible location of fractured zones. The seismic velocity data if available will be important to convert the time horizons to depth.

Expansion of mine to the north

The new information has further identified a risk area termed the Frontenac Point Anomaly referenced in the John T. Boyd Company 2015 review of Cargill's 2014 Annual Report to DEC. The report did not clearly explain what the Anomaly is, the exact location of the Anomaly or why there is a 1000 ft exclusion zone around the Anomaly.

Combining comments from John T. Boyd Company 2015, John T. Boyd Company's 01.29.2016 review of Cargill's 2015 Annual Report to DEC, and Cargill's Annual Reports to DEC for 2014, 2015 and 2016 with seismically-defined cross sections in a Spectra Environmental Group 2000 report and work currently underway in SaltWorks, confirms the anomaly is a thinned area of overburden above the Syracuse Formation. It is highly likely the glacial valley floor has down cut through the Onondaga Formation into the underlying sediments, resulting in a section of less than 300 feet of rock between the valley floor and the Syracuse Formation (Figures 1, 2).

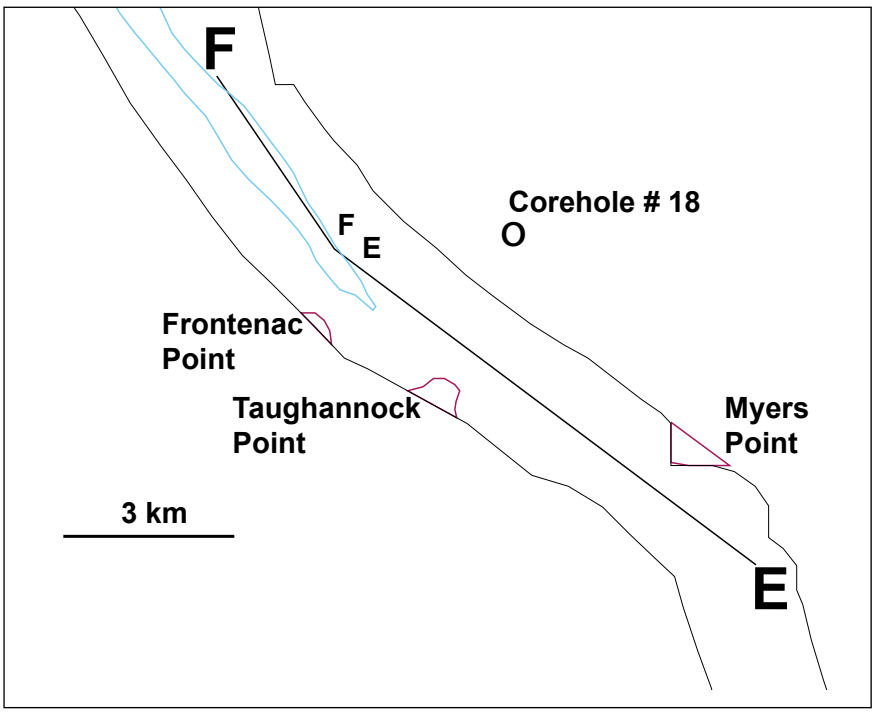

Figure 1. Location of cross sections E and F based on Spectra Environmental Group 2000 report. Blue line defines area of valley floor downcutting into Onondaga Formation.

Figure 1 shows the location of cross sections E and F based on maps from the Spectra Environmental 2000 report. The mapped downcutting area of the Onondaga Formation, outlined in blue in Figure 1), occurs along the cross section F. The resulting geologic cross section (Figure 2) confirms that the Onondaga Formation has been deeply cut by the glacial valley floor, resulting in a thinned layer of rock between the expected porous

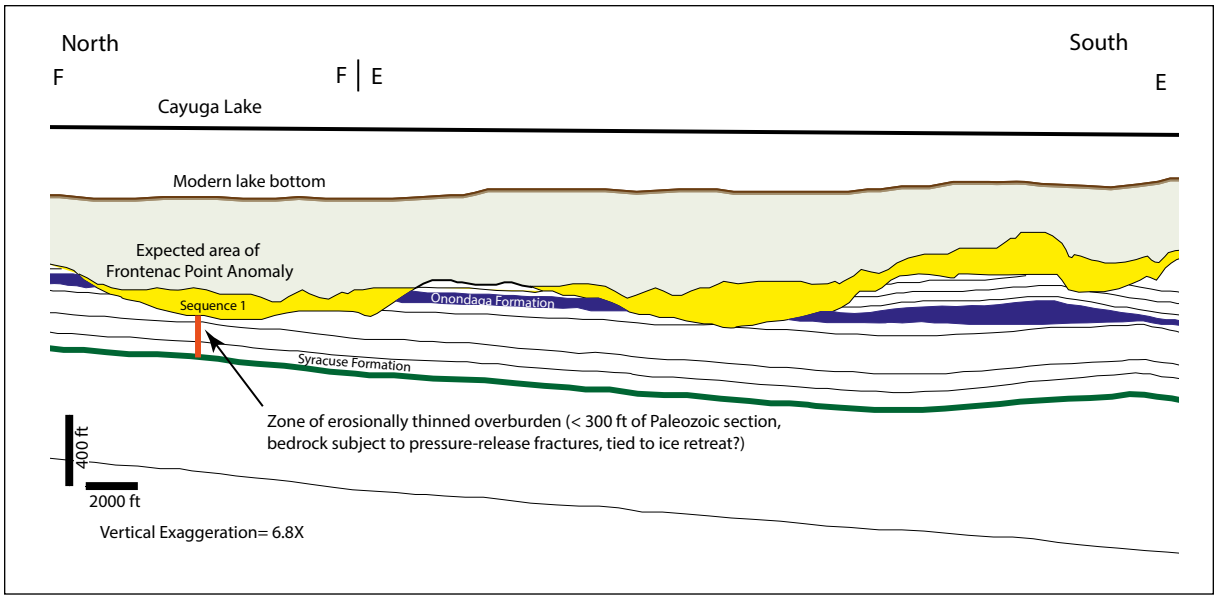

Figure 2. Cross section based on seismic data, revised from Spectra Environmental Group, 2000 report and integrating the results of a reinterpretation of public domain seismic currently underway in SaltWork Consultants. The section illustrates areas of deep valley floor cutting into Onondaga Formation. Location of shallow overburden of less than 300 feet (measured at the vertical orange line) between the valley floor and Syracuse Formation is situated in an area referred as Frontenac Point Anomaly. Sequence 1 glacial deposits in valley floor occur at the bedrock contact and are expected to be dominated by porous glacial outwash sediments.

glacial outwash of Sequence 1 in the valley floor and the rocks of the Syracuse Formation.

The section in Figure 2 is a geological cross section based on public-domain seismic data currently under study by SaltWork Consultants. Lake bottom is in brown, Sequence 1 glacial deposits in yellow, the Onondaga Formation in blue and the near top of mining area represented by top Syracuse Formation is in green. The deep downcutting of the valley floor into Onondaga Formation occurs in at least two areas. The deepest, with less than 300 feet of rock separating the valley floor from the Syracuse Formation is in the area of the Frontenac Point Anomaly. The rock section between the Sequence 1 at the valley floor and the Syracuse Formation is measured as less than 300 feet – location is shown on the vertical orange line. The thickness is currently estimated from seismic time. A more exact calculation of geological thickness requires detailed velocity information, which the DEC appears to have redacted when it released RESPEC's Corehole 18 study in September 2016. Such data may also have been obtained during Cargill's 2016 seismic acquisition program conducted by Bay Geophysical. The location of the thinned rock is expected to be an area of high risk for mining activity, especially if ice retreat facilitated pressure-release fracturing in the Palaeozoic bedrock (see Warren, 2016a,b).

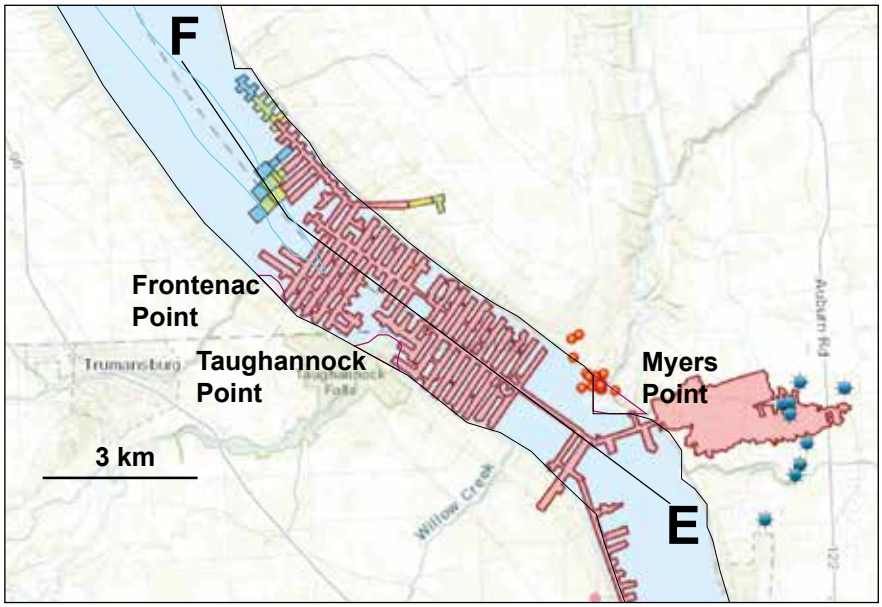

Figure 3. Location of cross sections, downcutting of Onondaga Formation and present mine location (red) and future mining areas (blue). Base map from Karen 2017. The deepened valley floor resulting in thin overburden over Syracuse Formation is expected to be inside the blue area.

The present mining areas in pink and future mining areas in blue and green are shown in Figure 3 are based on Edelstein, 2017. The expected future mining will be below the thinned area of overburden between the valley floor and Syracuse Formation, as shown on F section in Figure 2. Therefore, there is an as yet unquantified risk in further mining to the north and west below the valley floor.

A back-reaming plan for the construction of Shaft#4

Figure 2 shows there are multiple areas of contact between the Onondaga Formation/Oriskany Formation and the glacial floor deposits near the proposed location of Shaft#4 (labelled as Corehole # 18 in Figure 1). Therefore the risk of encountering a possible aquifer/water-breach zone during the back-reaming remains a high risk. Further seismic data is needed to confirm the extent of the anticlines and possible location of fractured zones.

The "2016 Cargill annual report to DEC indicates that the velocity model is now accurate with 17 layers- these data is needed for correct time to depth calculations from the seismic.

Cargill acquired extensive seismic in 2016 and said that a report was due in January 2017 to discuss the seismic results. It is expected that this report will accurately outline the area of the thinned basement, identify fracture zones and areas of concern about geological stability in the area. These are important data that are not presently available to SaltWork Consultants for evaluation. It should be independently evaluated before permission to proceed and expand is granted by DEC. That is, a full evaluation of these seismic data is critical in quantifying the risk associated with further mining north and west of the current mine area illustrated in Figure 3.

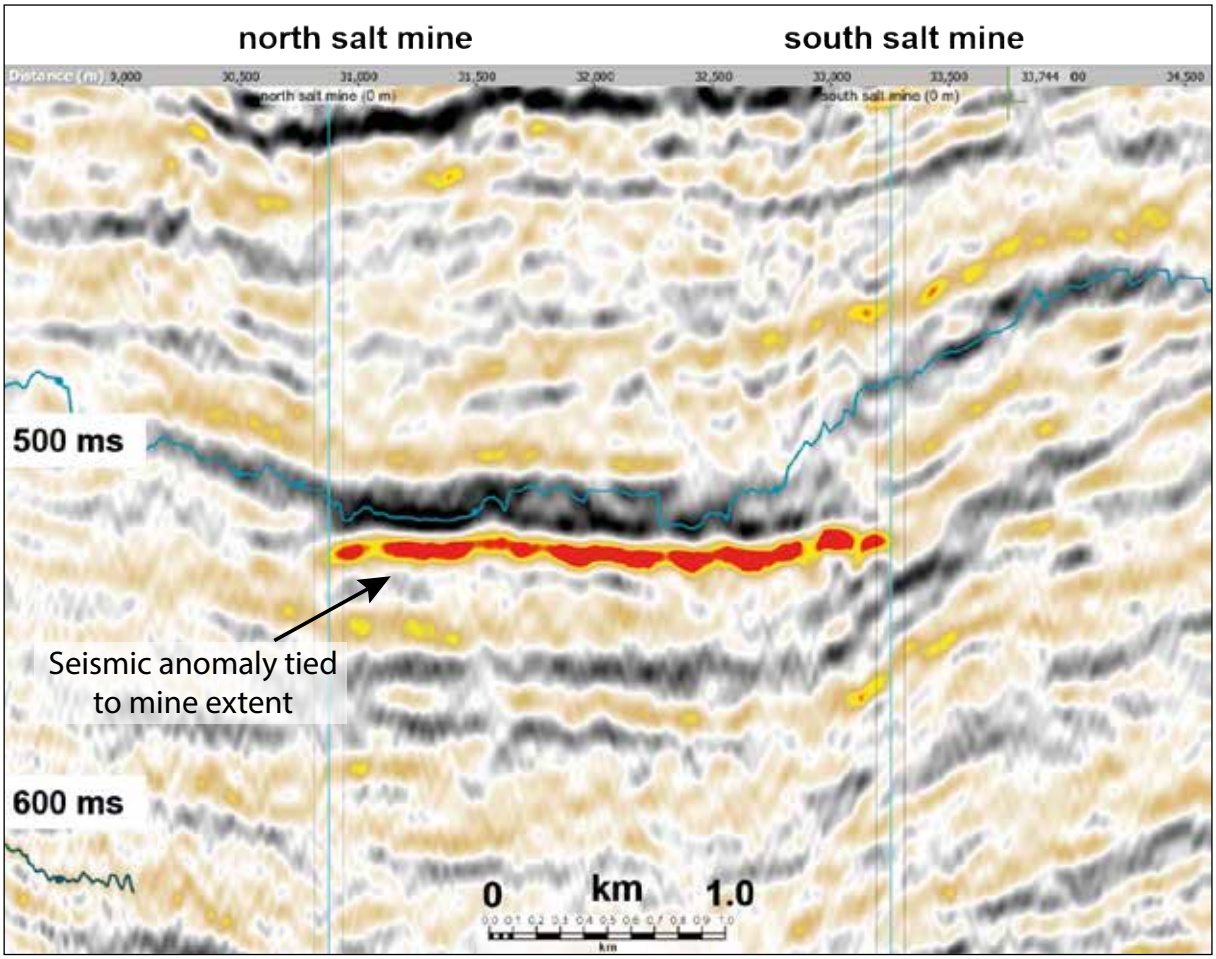

Figure 4. The distinctive high amplitude seismic anomaly recorded in the 2D Cayuga Lake seismic is correlated to the expected location of the mine at the time the seismic was shot. The present mine area extends beyond this anomaly.

Work underway in Saltwork Consultants, utilising public domain seismic data shot across Lake Cayuga, defines a seismic reflection that is expected to be the location of previous salt mining in the Syracuse Formation. This distinctive high amplitude seismic anomaly recorded on the 2D Cayuga Lake seismic, as shown in Figure 4, has been correlated to the expected location of the mine using general velocity values. This seismic was run more than ten years ago and the mine now extends beyond this area. But, the utility of a remote recognition technique for defining mine extent in a regional geological frame, via the application of the seismic technique, was not publically identified until the current work program by SaltWork Consultants. The new Cargill seismic data is therefore expected to accurately map the location of existing mining activity during 2016 in relationship to any possible geological weak zones recognised in seismic.

Conclusions

There is now multiple evidence that the Onondaga Formation has been downcut by the valley floor in the area of the mine. This thinned area of overburden between the valley floor and Syracuse Formation area is expected to be the Frontenac Point Anomaly referred in the referred in Cargill 2016 Annual Report to DEC. The report did not explain what the anomaly is, the exact location of the Anomaly or why there is a 1000 ft exclusion zone around the anomaly. It is expected that this is an area of thinning of bedrock overlying the future planned mining area.

Detailed evaluation of the recent 2016 seismic data is critical to determine the risk of future mining in the northern area. This information should be quantitatively evaluated by the DEC before granting permission for the current mine to expand north and west.

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