

## Subsidence Associated with Mining at the Cayuga Salt Mine

H.D.S. Miller<sup>1</sup>, G. Petersen<sup>2</sup>, D. Plumeau<sup>3</sup> and J. Rankin<sup>3</sup>

<sup>1</sup>International Mining Services

<sup>2</sup>Rock Mechanics Assist

<sup>3</sup>Cayuga Mine, Cargill — Salt Division

### ABSTRACT

An ideal opportunity was presented at the Cayuga Salt Mine in Lansing, New York, to monitor and record ground subsidence resulting from mining operations. The mining conditions giving rise to the subsidence were particularly favorable. A single 176 m wide high extraction panel was mined sufficiently distant from other mine development so as to effectively isolate it from the effects of that mining. The pillar layout in the panel was very regular. Subsidence surveys were carried out far enough in advance to obtain a zero subsidence baseline. The results showed that the influence of the mining-induced subsidence extended much further out laterally from the edges of mining than could be expected from a similar case in coal or hard rock mining. The time delay between the approach of mining and the subsequent effect measured on the surface also presented some interesting features in that virtually no subsidence was observed until the face had passed beneath the line of monitoring stations

The results have led to a significant overall conclusion. Owing to the yielding nature of salt and the subsequent closures of excavations mined in salt, the pattern and rate of ground subsidence occurring as a result of mining is considerably different to that experienced as a result of mining in coal measures or hard rock. This paper details the measurements made and discusses the results obtained.

### INTRODUCTION

The Cayuga Salt Mine is located in New York State, approximately 11 km north of the City of Ithaca, and is currently mining the No. 6, 4 m thick, salt bed, some 650 m below the surface. The mine has been in existence for over seventy years and both the No. 6 salt as well as the No. 4 salt, located 100 m above, have been extensively mined to the east of the shafts. Mining areas were developed starting in 1986 in a new area to the northwest. Extraction in the eastern area of the mine averaged more than 60% extraction on two levels, with one level, the No. 4 salt, being partly superimposed above the No. 6 salt. The log of a typical geological core hole (No. 17) is given in Fig. 1, and the geology of the northwest area of the mine appears to be fairly regular.

The northwest mining area is far enough away (more than 4 km) from the old mining areas so that it can be considered to be completely isolated. Figure 2 shows the overall layout of the mine. The NW1 development panel goes northwards, with panel U12 being driven at right angles from NW1 for a distance

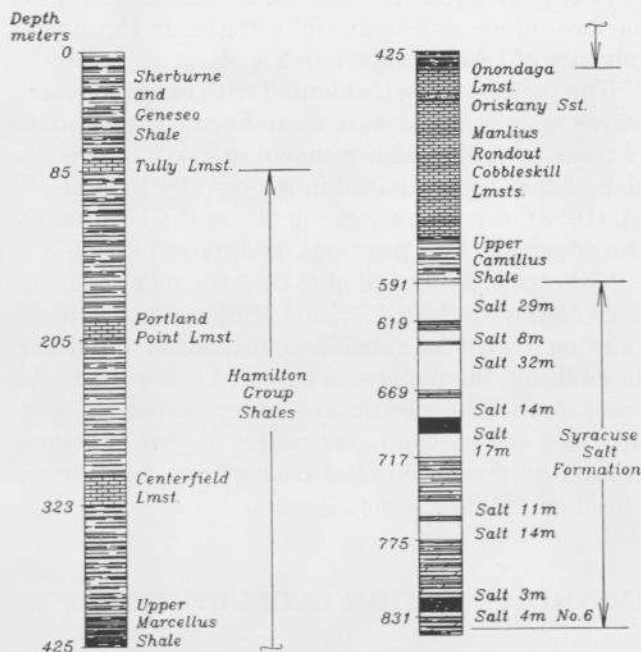


Fig. 1. Geologic section, core hole no. 17, Cayuga Salt Mine.

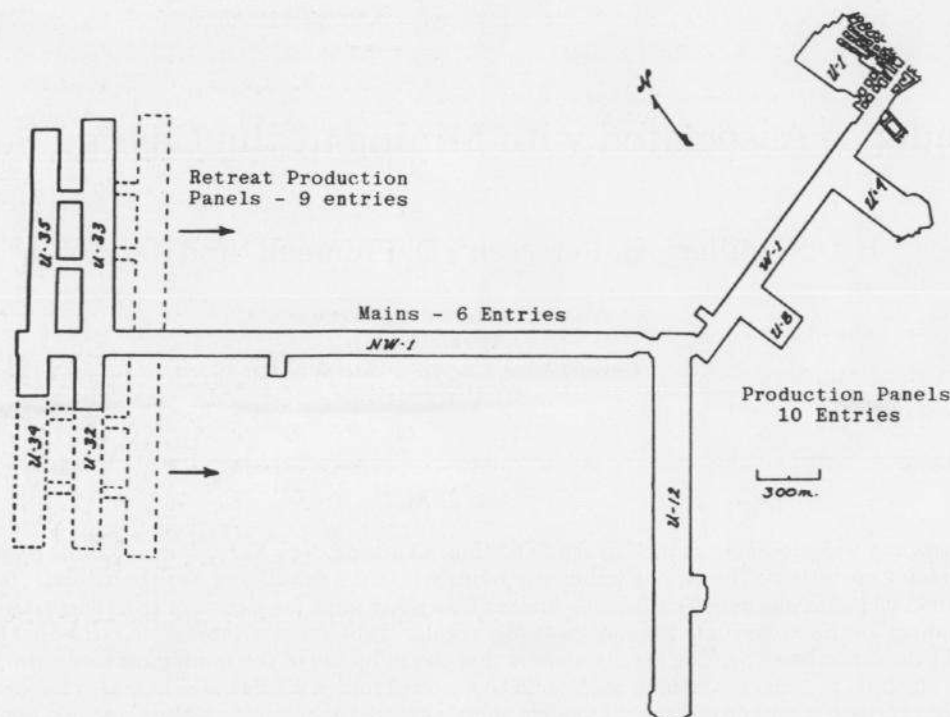


Fig. 2. North-west quadrant mining.

of 1650 m. This unit is 176 m wide, has ten entries and 15 m long notches cut into the abutments (see Fig. 3). The average mining height was 4 m, with an overall panel extraction ratio of more than 80%.

A row of subsidence stations was installed on surface, more or less at right angles to the line of advance of U12, as shown in Fig. 4.

The panel was instrumented with extensometers, stress meters and closure stations and the locations of these instruments are shown in Fig. 3. A description of the instrumentation is given by Petersen et al. (1993). Also shown in Fig. 4 are the locations of the advancing face positions on different dates.

This study consisted of taking the measured closure data from the U12 panel underground and correlating it with the subsidence measured on surface. In addition, the panel was modeled using the FLAC creep code. The elastic and creep constants were adjusted in the computer model to give the same results as measured, and conclusions were drawn based on the choice of constants.

#### INSTRUMENTATION: CLOSURE STATIONS

Closure measurements were made using a "Reed" type convergence rod. The frequency of readings

varied from twice a week initially, to once a week, once a month and finally once every 3 months, as the closure rate decreased with time and distance from the advancing face. The readings were made to 0.025 mm, with excellent repeatability.

Typical plots of the data are given in Figs. 5, 6a and 6b. Figure 6a shows the closure pattern across the panel and Fig. 6b, along the panel for the center closure stations.

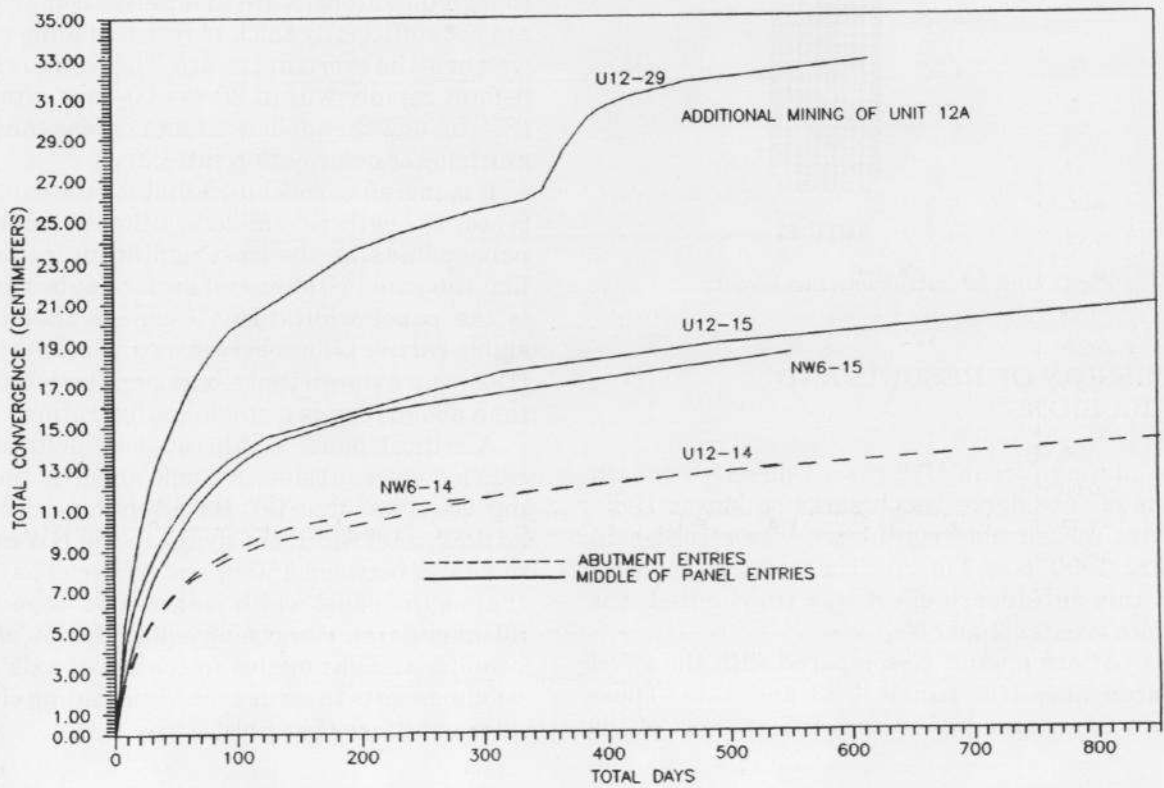
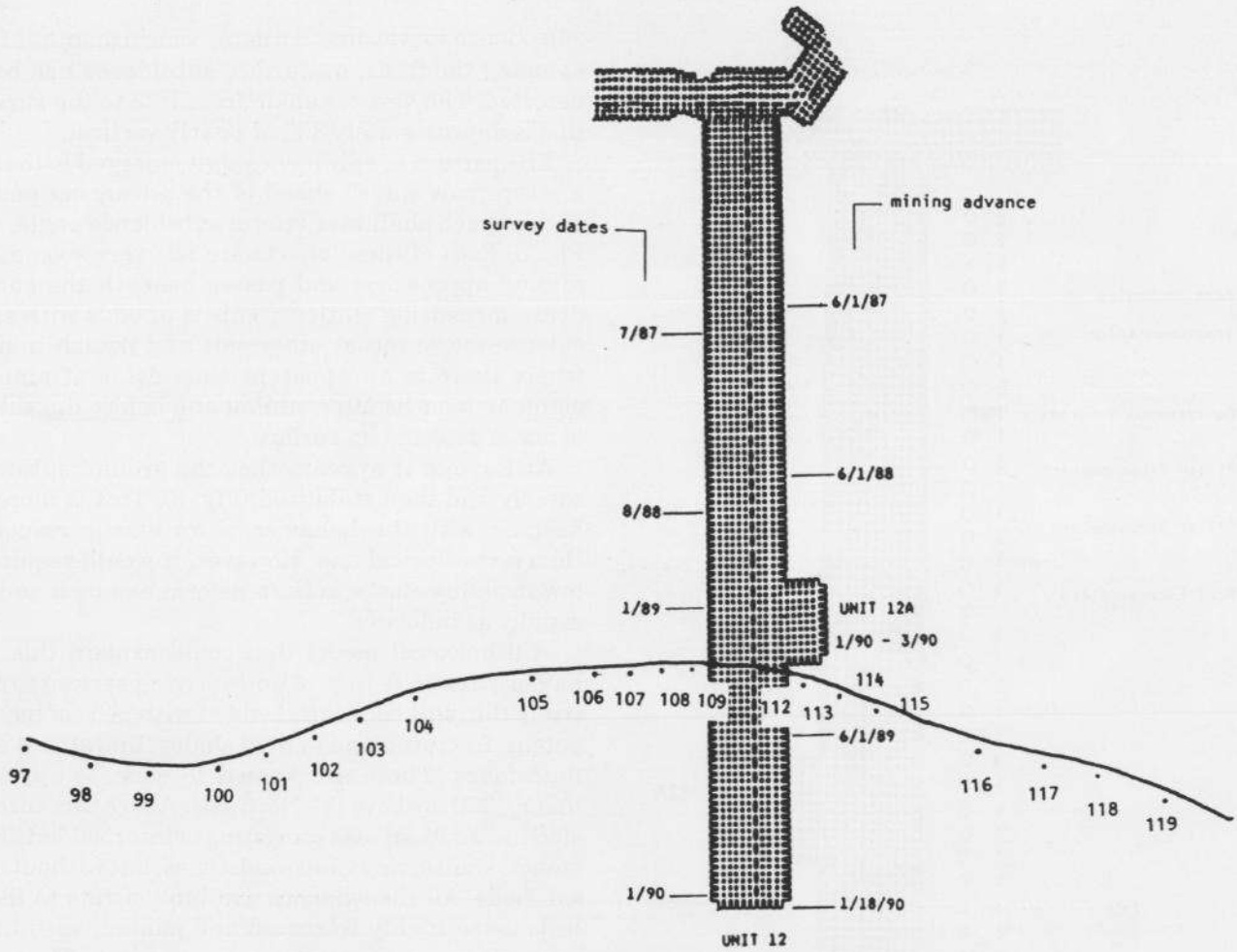
#### SURFACE SUBSIDENCE STATIONS

The subsidence benchmark station array consisted of steel survey pins drilled and cemented into concrete abutments as well as 1–2 m steel rods driven into the ground. Initially 16 benchmarks were installed over a distance of 1800 m, centered over the U12 panel axis. This was later extended to 25 benchmarks over a 3400 m length.

Levelling surveys were conducted by an outside firm of professional surveyors, starting in 1987.

The face positions were plotted for the dates on which the subsidence surveys were carried out, and these are given in Fig. 4, as well as the position of the subsidence traverse line on surface.





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Top: Fig. 4. Unit 12 panel and subsidence station array.

Bottom: Fig. 5. Room closure Unit 12.

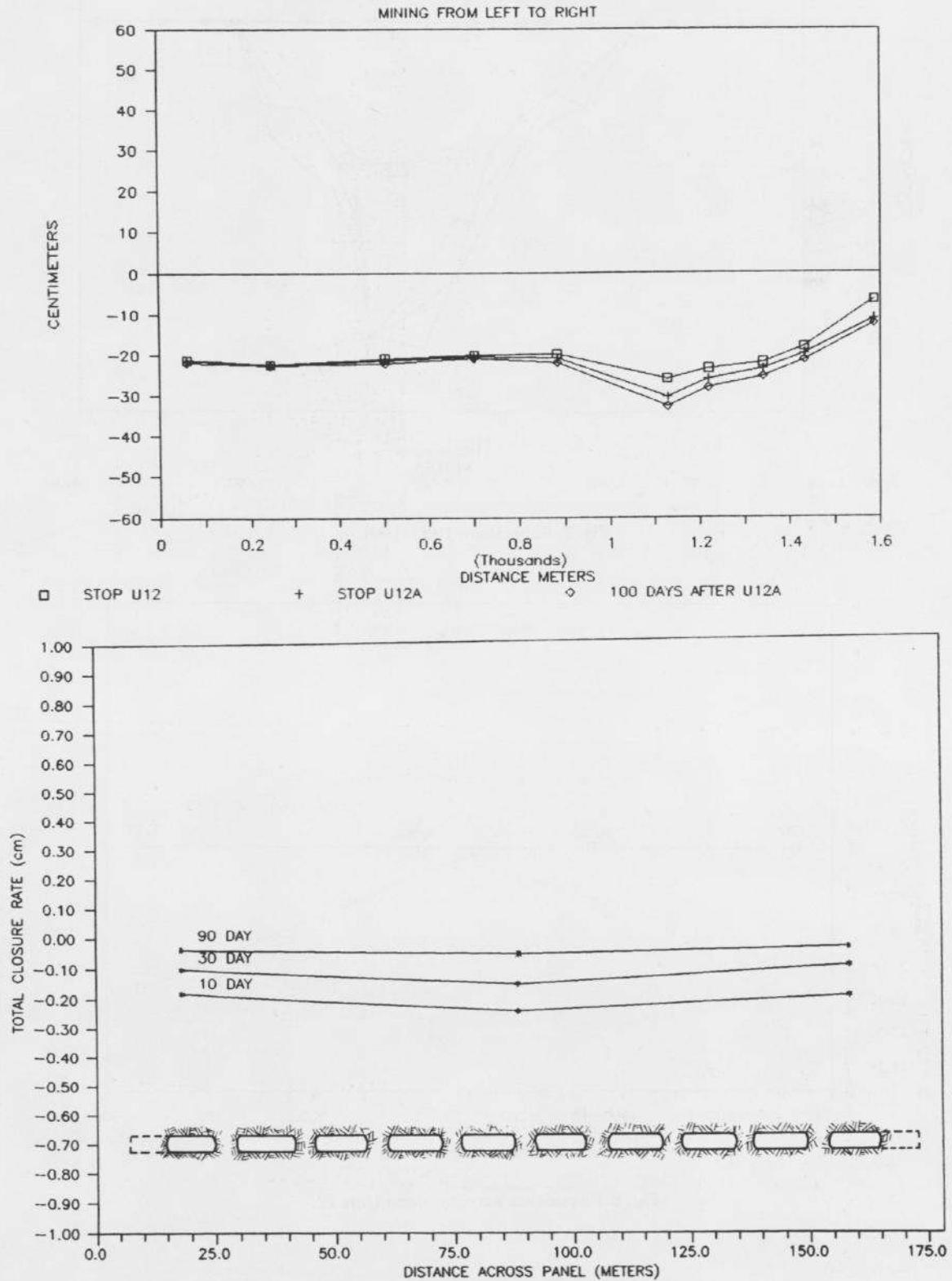


Fig. 6. Top: (A) Closure rate profile across panel. Bottom: (B) Closure rate profile across panel.

The mining configuration consisting of panels 150 m wide separated by barrier pillars with a minimum width of 70 m is therefore a stable one, not only from the consideration of panel closure rates but also from the point of reducing surface subsidence effects, particularly ahead of the advancing panel face.

Computer modelling is currently being carried out using the FLAC computer code to develop a realistic model to simulate the effects of mining on panel closures and surface subsidence. Initial results show that in order to accurately simulate actual closures and subsidence, laboratory-based rock mass strength parameters are of little use. For example,

much lower modulus values have to be used as well as arbitrary selection of values for creep constants.

However, the measurements of room deformations and surface subsidence have been invaluable in assessing the performance of different mining layouts.

#### REFERENCE

- Petersen, G., Plumeau, D. and Rankin, J., 1993. Practical approach to mine design at the Cayuga Rock Salt Mine. In: H. Kakihana, H.R. Hardy, Jr., T. Hoshi and K. Toyokura (Editors), *Seventh Symposium on Salt*, Vol. I. Elsevier, Amsterdam, pp. 259-264.