MUDBOILS IN THE TULLY VALLEY, ONONDAGA COUNTY, NEW YORK

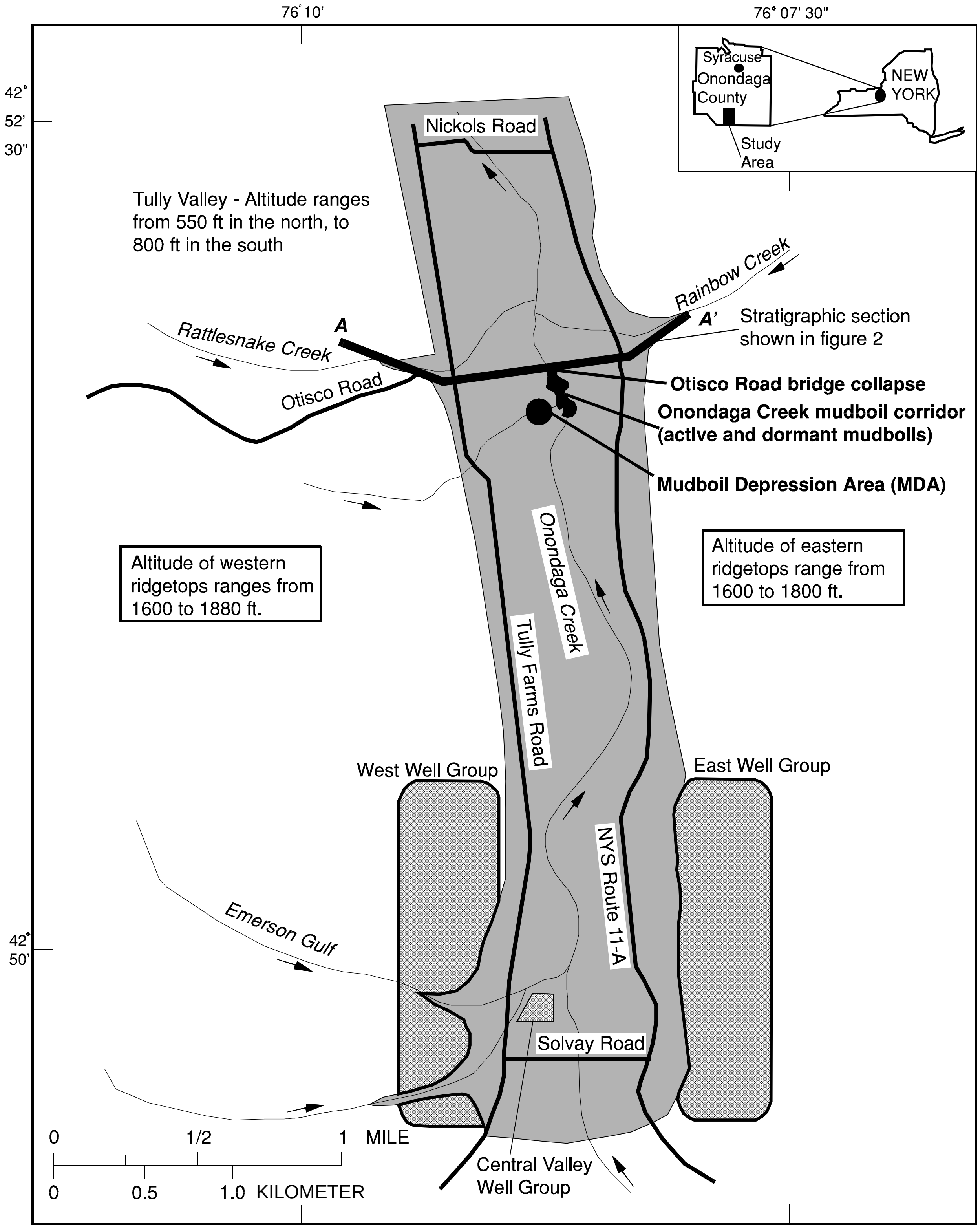
William M. Kappel (U. S. Geological Survey, Ithaca, New York)

The discharge of turbid ground water and fine sand to the land surface in the Tully Valley, approximately 20 mi south of Syracuse, New York, has formed a series of mudboils (fig. 1). The volcano-like cone of a mudboil can be several inches to several feet high and from 1 ft to more than 30 ft in diameter. Where mudboil activity is persistent, the removal of sediment at depth has caused land subsidence. Depending on the depth of the source zone, individual mudboils discharge fresh or brackish ground water. The temperature of freshwater discharges ranges between 45 and 55 °F; the temperature of brackish water discharge is nearly constant at 51 °F. Mudboil activity may be natural or may be associated with a large solution salt-mining operation that began in the southern part of the valley in the late 1800's and ceased in 1988. The mined salt beds range from 1,000 to 1,400 ft below land surface (fig. 2). The northern extent of the brining operation is 1 mi south of the mudboil area; the northern limit of its effect is unknown. Dissolution of the salt beds initially utilized injected surface water but since the late 1950's dissolution has occurred only under natural conditions, involving ground-water infiltration to the salt beds from the surrounding fractured bedrock and possibly from the more permeable unconsolidated glacial deposits in the Tully Valley.

The earliest known mudboil in Tully Valley, reported in the Syracuse Post Standard on October 19, 1899, was apparently localized and short-lived. From 1899 to the 1970's, the mudboils within the Onondaga Creek mudboil corridor (fig. 1) appeared and dissipated over a span of several weeks to a few months but had no long-term effect on the water quality of Onondaga Creek and Onondaga Lake, 20 mi downstream. Active mudboils became increasingly persistent during the mid-1970's, causing turbid discharges that degraded the quality of Onondaga Creek. Before the mid-1980's, relatively fresh ground water was discharged from what is now called the main 'mudboil depression area' (MDA), located 1,500 ft south of Otisco Road (fig. 1). Since then, however, the discharge has been more brackish, and land subsidence (locally as much as 15 ft) has progressed outward. In June 1991, a new mudboil appeared in Onondaga Creek just upstream of the Otisco Road bridge (fig. 1), and within 2 months the bridge collapsed. Subsidence around the 150-ft radius of this collapse area ranges from several inches at the perimeter to more than 5 ft at the bridge.

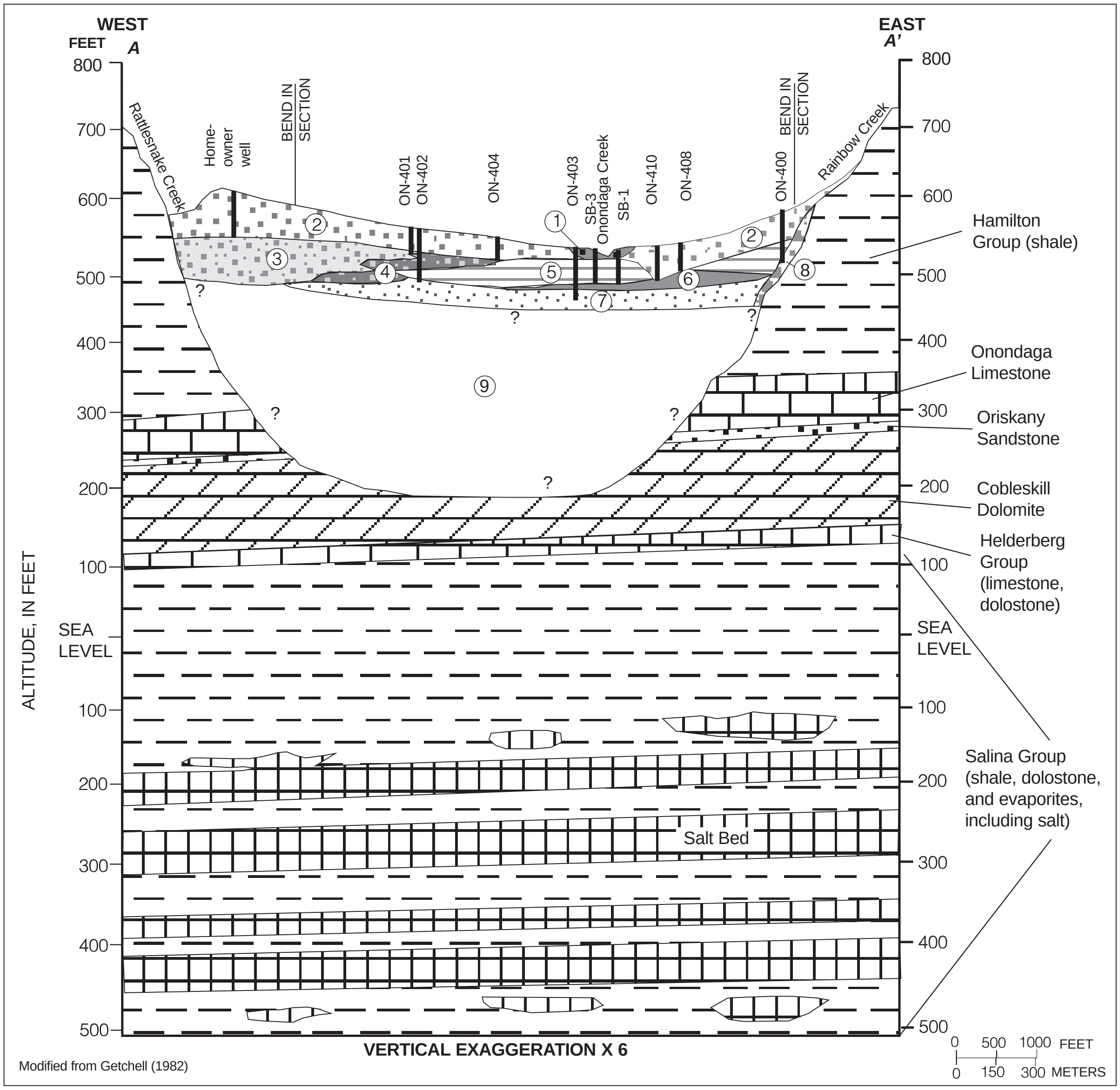
Flow measurements from the MDA during the 1992 water year indicate that there are seasonal variations in the amount of ground water discharged by the mudboils. Approximately 180 gal/min is discharged in the fall, compared to more than 360 gal/min in the spring. The mudboils, however, do not respond to individual storms. The average daily sediment concentration in the MDA discharge to Onondaga Creek for the 1992 water year is approximately 7,300 mg/L and the average sediment load (as clay, silt, and fine sand) is 35 tons per day.

The stratigraphic sequence of the glacial deposits (fig. 2) was defined through a shallow (<100 ft) drilling program. A source zone for water and mudboil sediments was identified beneath a sequence of silt- and clay-rich deposits. When the test wells penetrated this mudboil source zone, water, silt, and fine sand moved up the test-well casing, and water flowed at 3 to 5 gal/min at the land surface. When the casing was shut-in, the source zone had a measured hydraulic head about 600 ft above mean sea level, which is significantly above the surface of Onondaga Creek (540 to 545 ft) and the land surface of the MDA (550 to 555 ft).



Base from Otisco Valley Quadrangle, 1955 1 : 24,000

Figure 1. Geographic features in the Tully Valley, Onondaga County, New York. Tully Valley is about 20 miles south of Syracuse, New York.



ALLUVIAL DEPOSITS

1. **FLOOD-PLAIN AND MUDBOIL DEPOSITS** - silt, sand, and gravel.
2. **FAN DEPOSITS** - mostly silty sand and gravel deposited by Rattlesnake and Rainbow Creeks.

DELTAIC AND GLACIOLACUSTRINE DEPOSITS

3. **LAMINATED SAND AND SOME SILT/CLAY** - mostly fine to medium sand interbedded with minor amounts of silt and clay.
4. **LAMINATED SAND AND SILT/CLAY** - very fine sand interbedded with silt/clay.
5. **LAMINATED CLAY WITH SOME SILT** - mostly clay interbedded with some thin, very fine sand layers: forms confining unit over liquifiable sand and silt (unit 7).

DELTAIC AND GLACIOLACUSTRINE DEPOSITS cont'd

6. **CLAY** - massive, forms confining unit over the liquifiable sand and silt described below.
7. **SAND AND SILT** - massive, mostly very fine to medium sand and silt with trace amounts of coarse to very coarse sand deposits under artesian conditions in low parts of the valley, commonly heaves-up into well casings and probably is the source of sediment issuing from the mudboils.

OTHER GLACIAL DEPOSITS

8. **TILL** - pebbles embedded in a clay matrix, may underlie entire glacial sequence in the valley.
9. **MIXED GLACIAL DEPOSITS** - Two sequences of lacustrine clay and silt grading to sand, gravel, and boulders with a possible till deposit along the bedrock surface.

Figure 2. Generalized section *A-A'* (location shown in figure 1) of the Tully Valley near Otisco Road, showing stratigraphy of the unconsolidated and bedrock units.

The causes of the mudboils are presently unknown because the hydrogeologic system is complex and incompletely understood. Factors that could be related to their origin, location, and water quality are:

1. Location*:* The mudboils are located near Onondaga Creek between the only two major side-wall stream valleys that enter the glaciated Tully Valley. As fine-grained materials were being deposited in front of the glacier, coarser materials were being deposited as foreset beds and/or fans from the two side valleys. The intersection of these two deposits may have created a zone of structural weakness, especially near the stream, where overburden stresses would be least due to the lower elevations of the streambed.

2. Hydrostatic pressure: The earliest reported mudboils were along Onondaga Creek, just downstream from two mills and a dam. The hydrostatic load placed on varved lacustrine deposits underlying the mill pond could have caused hydraulic piping through preexisting zones of weakness and created the first mudboil. Subsidence of the land surface as materials at depth were removed caused the process to become self-perpetuating.

3. Excavation and erosion: An oil pipeline, laid in the Tully Valley in 1931, crosses through the eastern end of the MDA. Even though mudboil activity and subsidence in this area were not reported until the 1950’s, the pipeline had to be lowered in August 1974, reportedly due to erosion caused by Hurricane Agnes (June 1972), the excavation temporarily reduced the overburden stress and coincided with increased mudboil activity.

4. Cessation of pumping: The cessation of the solution salt-mining field’s annual pumping of approximately 1 billion gal of brine in the late 1980’s caused the hydraulic head in the deep sand and gravel zone to increase by 70 ft or more, and this increased head coincided with the onset of increased mudboil activity and changes in the quality of water discharged from the MDA.

Subsidence of the land surface in the Tully Valley has occurred over the past 100 years, but the causes of this subsidence are varied. In the brine fields, uncontrolled solution mining of the deep salt beds has resulted in the collapse of large unsupported spans of rock materials immediately above the salt (Fernandez, 1991). In some cases the subsidence is gradual and occurs over a large area (tens of acres) as the upper bedrock units sag into the lower collapse area. In other cases the subsidence is confined to a small area (hundreds of square feet) due to the development of a “chimney” through the rock formations above the collapse area, which creates a sinkhole at the land surface (Fernandez, 1991).

Along Onondaga Creek and in the main MDA, land-surface subsidence is related to the discharge of ground water and fine-grained materials from the subsurface to the land surface where stream erosion moves the discharged mudboil sediments downstream. Continued discharge of subsurface materials and subsequent removal leads to land subsidence (see Helm abstract for discussion of related physical mechanisms in the formation of earth fissures). This process is gradual but perceptible, as noted in the collapse of the Otisco Road bridge.

A third type of subsidence is suspected but is currently undocumented—subsidence due to the compaction of fine-grained materials resulting from the aggressive pumping of ground water during the last 20 years of solution mining in the Tully Valley brine fields. The cessation of pumping resulted in a 70- to 100-ft recovery of water levels in the deep sand and gravel and probably brought this type of subsidence to a halt. Although the following information is circumstantial, it may indicate that this form of subsidence has occurred in the Tully Valley:

1. Measured datum changes: Subsidence of 1 to 2.5 ft at several locations on the floor of Tully Valley outside of the solution-mined areas has been measured at several temporary bench marks established by the brine-mining company (Mr. Jim Tyler, Allied Corporation, oral commun., 1992).

2. Changes in penetration rates: Decreases in drilling penetration rates at the base of the massive clay unit (unit 6, fig. 2) that overlies the sand and silt unit (unit 7, fig. 2) were noted during the shallow drilling program. Split-spoon samples collected from the middle part of the massive clay unit were advanced with the weight of the drill rods. The lower part of the massive clay unit required increasing down-pressure (as high as 450 lb/in^2) to collect several split-spoon samples.

3. Structural damage: Large-building foundations are reported to have separated, cracked, or subsided in all parts of the Tully Valley, both in and outside of the solution mining area.

Study of the Tully Valley mudboils will continue through 1993. Subsidence will be monitored at the main MDA to determine if any planned remedial actions will affect rates of subsidence. A deep well will be drilled to determine if there is a collapse feature in the bedrock beneath the MDA or if the saltbeds have been solutioned-out in this area. Ground-water samples from selected water-bearing zones in the bedrock, the basal sand and gravel unit, and the shallow mudboil source zone will be collected and compared with samples collected from fresh and brackish water mudboils to determine possible source zone(s) feeding the mudboils.