Subsidence Following Groundwater Drawdown by Excavating of Deep Shafts in Granite in Mizunami, Japan in 2004-2014

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JAEA Deep Shaft Excavating Project in Mizunami, central Japan

Tono Geoscience Center (TGC), Japan Atomic Energy Agency (JAEA) has been carrying out a wide range of geo-scientific research in order to build a firm scientific and technological basis for geological disposal.

One of the major components of the ongoing geoscientific research program is the Mizunami Underground Research Laboratory (MIU) Project in the Tono area, central Japan.

Two 1,000m* deep shafts and several drifts will be excavated for geoscientific research and applicability of engineering techniques will be estimated (MIU, 2002). (*: 1000 m depth was a plan n 2002, and stopped at 500 mdepth in 2011.)

Fig.1 Index map of Mizunami.

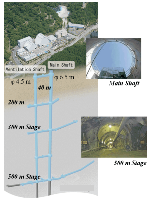

Fig.2 Cross section of 500 m deep shafts at MIU.

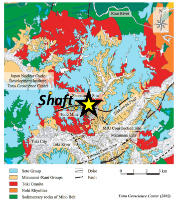

Fig.3 Geological map around MIU. Granite is distributed as bedrock.

Leveling Network and Detected Subsidence nearby Shafts in 2004-2012

Tono Research Institute of Earthquake Science (TRIES) establishes the monitoring system to detect the grand water level and ground deformation around the 500 m depth shafts since 2002. Water level was observed at the borehole locating 300 m south from the shaft (shown in blue square in Fig.4) in 2002. Precise leveling is also repeating in the nearby area of the shafts shown in Fig.4. In 2012, leveling network is extending in 2012, shown in Fig4.)

Vertical deformations along the leveling route of BM 0-2-9900 -2 are shown in four periods of 2004.2 – 2007.3 - 2011.3 -2012.3 – 2012.9 in Figure 5. Except the 2011.3 -2012.2 period, subsidence is distinguished. the maximum subsidence is detected close to BM2, and it is about 2cm for 8 years.

Deformations are referred to the BM0, locating the southeast part of the leveling route.

Uplift of about only 2 mm is observed in the period of 2011.3 - 2012.2, just corresponding to the occurrence of 3.11 Tohoku M9.0 Earthquake. Uplift observed in 2011.3 – 2011.8 is small and in few benchmarks, it observed more large and extended in 2012.3.

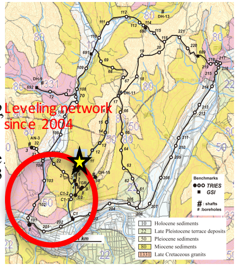

Fig.4 Location map of the precise leveling network.

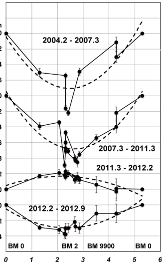

Fig.5 Vertical deformation nearby the shafts for four periods in 2004 – 2012.

Drain, Water Level Drop, and Subsidence at Shafts

Draining from shaft lead the ground water level change in Togari borehole and subsidence at BM 2 (Fig. 6). For 11 years until 2015, discharge of ground water is over 800 m3/day, water level drop over 80 m is observed at the borehole, and a subsidence over 22 mm is detected at BM2 close to the shaft.

1. Sudden water level drop after the flood from 200 m depth in shaft in 2005 summer.
2. Water level recovering at the discontinued draining in 2005 fall.
3. Water level drop after re-draining of 600 m^3/day in 2006, and reached over 800 m^3/day in 2013.

In 2011 Tohoku Earthquake, large water level ascend over 15 m is observed in Togari borehole, and uplift of 2 mm is detected at BM2 in 2012.2.

Consequently, large draining of 600 m^3/day from shaft cause the water level down of 60 m and subsidence of 20 mm.

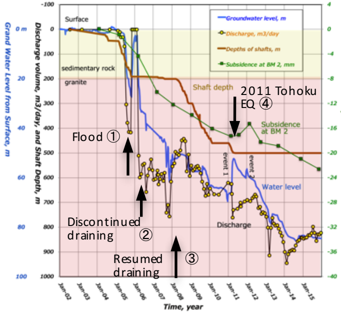

Fig.6 Time series of water level change, drain volume, ground deformation and shaft depth.

Subsidence around Shafts in 2012-2015

In 2012, we extend the precise leveling network toward north-east direction. Finally, the length of leveling route exceeds 30 km. and we could discuss the vertical deformation over 5 km x 5 km area. Precise leveling are repeated every year until 2015. As results of repeated leveling,

1) Leveling errors are within ±1 mm, shown in Fig.7
2) A significant subsidence of 6 mm for 3 years is detected beside of the shafts and in the downstream area of groundwater system, shown in Fig.8

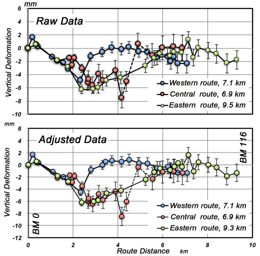

Fig.7 Vertical deformation along the leveling routes In 2012-2015.

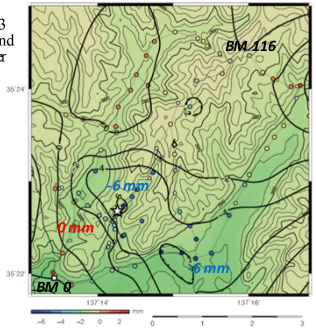

Fig.8 Vertical deformation contour map in leveling network

Base Structure of Groundwater System

Base rock is granite in the region, and base structures in in the groundwater system are estimated using electro-magnetic and seismic surveys by JAEA shown in Fig.9. Base rock distribution is controlled the groundwater system, and groundwater are following the boundary of granite and sediments.

Main groundwater system around the shafts is southward stream from north, named Hiyoshi Chanel, and second one is the southeast ward stream from northwest, named Tsukiyoshi Channel.

Additionally, the channels join in the southeast of the shafts, and the altitude of the entrance region is about 0 m above sea level. One groundwater basin is formed with 50 – 100 m depth in the entrance region.

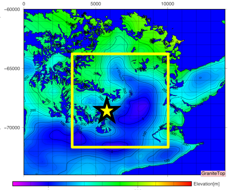

Fig.9 Contour map of granite top surveyed by JAEA.

Cross Section of GW System around the Shaft

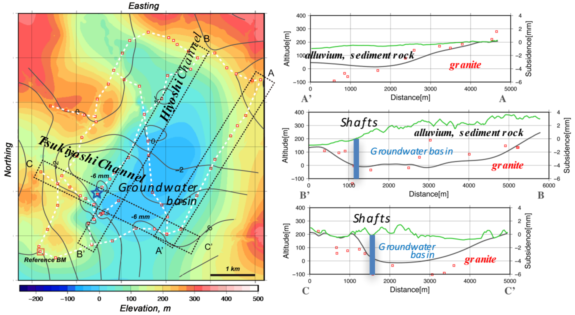

Fig.10 Contour maps of vertical deformation in 2012-2015 and granite top (left) and cross sections of the ground surface and granite top, and vertical deformation (right).

Subsidence are observed not only in the neighborhood of the shafts, but also the downstream of the groundwater system, where is composed a groundwater basin. Additionally, large subsidence s are detected in the area of thick alluvium/sediment rock, shown in Fig 10 left.

Conclusion

1) Excavating 500 m depth shafts with discharging of 800 m^3/day, trigger groundwater drawdown of 80 m, and subsidence of 2 cm nearby the shafts. The subsidence also detected 2 km far from the shafts.
2) As the field is located in meso-mountainous region, groundwater system is not simple. Discharging is intimately related with the groundwater system and groundwater basin.
3) In the test field of mass-discharging, it is necessary to make monitor by not only groundwater but also the ground deformation using with ground survey.