Ogoya Underground Laboratory (OUL)

Low Level Radioactivity Laboratory (LLRL),
Kanazawa University

History of Ogoya Mine and Ogoya Underground Laboratory, OUL

Entrance of OUL
The liquid nitrogen generator is on the left (generating capacity: 80 L a day).

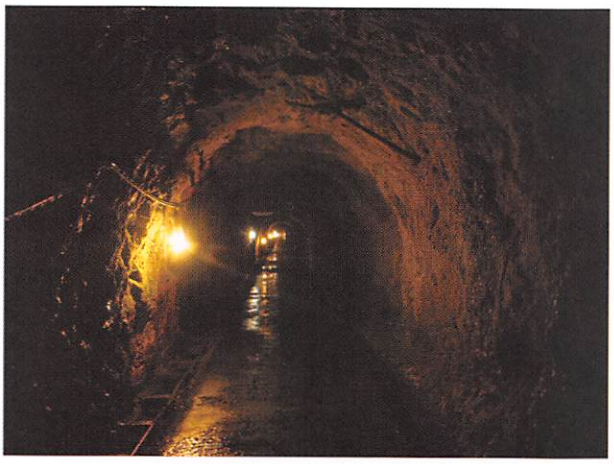

Photo 1. Inside of Ogoya-Kuratani Tunnel, April 2009.

- The 1600s - the second half of the 1800s: Ogoya Mine, located about 20 km southeast of Komatsu, Ishikawa, was operated as a gold mine for over 30 years before being closed.
- After the second half of the 1800s: Operation was resumed as Ogoya Copper Mine which had one of the largest outputs in Japan in this era.
- End of 1971: Ogoya Copper Mine was closed. The mining town which had once been crowded with more than 2600 residents withered away. Ogoya - Kuratani Tunnel which had been a road used by travelers to and from Ogoya and for conveyance of goods was also closed (Photo 1).
- 1991: Construction of OUL was started. Permis-sion to use the road tunnel was obtained from the Komatsu City government to prepare a facility for the measurement of low level radioactivity which cannot be measured aboveground because of the noise which originates in cosmic rays. The ruined tunnel was improved in four years by hand.
- Jan.1995: Two detectors were set up in the tunnel and low level counting was started.
- Feb. 18, 1995: The first low level measurements were made for cosmogenic nuclides in the "Neagari mete-orite".
- April 2008: The 18^{th} Ge semiconductor detector was set up.
- March 2009: Tunnel maintenance was undertaken and the tunnel floor was paved with asphalt.
- Now: OUL has 12 well, 6 planar, and 1 coaxial Ge detectors. All detectors have high efficiency and ultra low background specifications. OUL has become worldwide as an underground laboratory for low level counting.

Underground laboratories and detectors for low level radioactivity measurements

There are about ten facilities in the world located 100 - 1500 m below ground for measurements of rare physical phenomena, such as a cosmic ray neutrinos and double beta decay. In Japan, these are Institute, for Cosmic Ray Research which is an inter-university facility of the University of Tokyo that runs Super-Kamiokande Experiment in Kamioka Observatory (a former mine 1000 m below ground (2700 mwe)) and Oto Cosmo Observatory (the underground laboratory of Osaka University located in Oto-mura; 500 m below ground).

There are a few underground laboratories worldwide for low level radioactivity measurements as shown in Table 1. In Japan, they are OUL and Institute, for Cosmic Ray Research which has a facility at Kashiwa, Chiba branch campus of the University of Tokyo (20 m below ground). In OUL, the use of 19 detectors is exceptional and all the detectors provide excellent counting efficiency.

Table 1. Underground laboratories and detectors for low level radioactivity measurements.

	Lab.	Loc., Country	Depth (m)	mwe	Ge Relative Eff%, Detector type (C: coaxial, W: well, P: planar)	BG (d^{-1} kg^{-1}), 0.04-2.7MeV, (veto BG)
CELLAR	IRMM	Geel, Belgium	223	500	C (60%, 106%, 50%), P (8%)	260, 357, 1894, 1317
CELLAR	Max-Planck Inst.	Heidelberg, Germany	15	25	C (22%, 31%, 37%), W (17%)	2971, 2949 4052
CELLAR	VKTA	Dresden, Germany	47	110	C (30%, 41%), W (30%)	9713, 17285, 3870
CELLAR	LSCE	Frejus Tunnel, France	1750	4800	W (215cc, 427cc, 910cc)	707, 301, 186
CELLAR	INFN-LNGS	Gran Sasso, Italy	1400	3800	C (120%, 100%)	87, 30
CELLAR	IAEA-MEL	Monte Carlo, Monaco	14	35	C (100%, 170%), W (150%, 200%)	8136, 6096 (1368,840), 5400, 6960 (1632,1008)
CELLAR	ARCS	Seibersdorf, Austria	0		P (55%, 55%)	129600 (9242)
CELLAR	PTB	Braunschweig, Germany	925	2100	88%, 94.5%	1135, 278
CELLAR	Univ. Iceland	Reykjavik, Iceland	165	300	NaI (Tl)	
OUL	**Ogoya Underground Lab.**	**Komatsu, Japan**	**135**	**270**	**C (94%), W (73%, 71%, 71%, 71%, 65%, 56%, 56%, 56%, 50%, 37%, 36%), P (18%, 34%, 34%, 22%, 22%, 18%)**	**788, 1451, 1181, 1800, 2505, 1887, 1961, 2471, 1732, 1591,1945, 2286, 1333, 1216, 2714**

CELLAR: Collaboration of European Low-level underground LAboRatories (2003)

Features of OUL

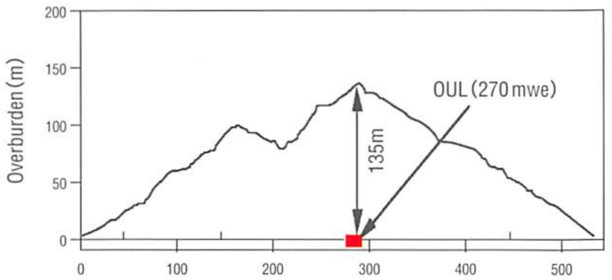

Fig. 1. Sectional view of Ogoya Underground Laboratory (Ogoya-Kuratani Tunnel). The entrance is on the left, and the unit of the abscissa is in m.

Photo 2. OUL counting room and detector clusters.

In gamma ray measurements, it is important to reduce the background derived from cosmic ray components (muons), activation of shielding materials, and secondary neutrons. It is difficult to reduce this component by conventional shielding aboveground.

Location of OUL

OUL is located about 20 km southwest of Low Level Radioactivity Laboratory (LLRL) of Kanazawa University. It takes only 30 min by car from LLRL or 40 min from JR Komatsu Station or Komatsu Airport, so that OUL is the world's most convenient underground laboratory to reach.

OUL is in a 546 m tunnel of the former Ogoya Copper Mine, which closed in 1971. It is located 270 m from the tunnel entrance, where the overburden is 270 mwe (Fig. 1).

Detectors and shielding in the OUL

OUL has 12 well, 6 planar , and 1 coaxial Ge detectors, as shown in Table 2. In order to measure a wide energy range from 20 keV to about 3 MeV, the planar detectors have large diameters and thicknesses of 2 to 3 cm and the well detectors have also large diameters. For most of the detectors, ultra low-background aluminum was used for the end-cap. The cryostat is the J-type and/or U-type and the preamplifier is located outside the lead shield. The lead shield is 20 to 25 cm thick, and its upper part is covered by 10 to 15 cm of iron. The inner 3 to 5 cm of the lead shield is made of lead refined 200 years ago. The space near the detector head is filled with Hg shield encapsulated in a polyethylene bag and nitrogen gas from the Dewar is blown to the top of the end cap. One of counting room is shown in Photo 2.

Background count rates

Table 2 also lists the specifications and performances of Ge crystals and background counting rates. The integrated background count rates of most of OUL detectors are less than 3 min^{-1}.

Fig. 2 shows the muon intensity (solid line) expected underground and the background count rate of the detectors listed in Table 1 which are normalized to aboveground values (shown as the green BG value of ARCS in Table 1) as a function of depth. The muon intensity decreases with depth, but the background count rate of the detectors does not decrease so much. The background count rates of OUL detectors (green points) are about 1/100 of the aboveground values, and are almost the same level as in facilities deeper than 1000 mwe, because the detectors have an effective massive shield, the radioactivity in the tunnel rock is comparatively low, and the tunnel is ventilated automatically so that the radioactivity in the air is also low. These are the reasons why OUL detectors can measure low level radioactivity, although they are located at a depth of only 270 mwe. It is estimated that the effects of secondary neutrons are approximately 1/100 of the effects aboveground. Therefore, the background count level in OUL makes it a top class facility.

Other feature

Besides radiation measurements, OUL also provides a low dose space.

Table 2. Specifications and performances of Ge crystals and background counting rates.

name	Type (Al end cap)	Relative Eff, size, volume	BG (min^{-1})
I	planar	28cm^2 x 2cm (18% ,56cm^3)	0.48
J	planar	38cm^2 x 3cm (34% ,113cm^3)	0.57
K	planar	38cm^2 x 3cm (34% ,113cm^3)	0.52
L	planar	28cm^2 x 2cm (18.2%,56cm^3)	0.57
M	planar	28cm^2 x 2.8cm (22%,78.4cm^3)	
N	planar	28cm^2 x 3cm (22%,79cm^3)	
C	well (10mmϕx40mm)	37% (61ϕx56mm,150.8cm^3)	0.9
D	well (21mmϕx62mm)	56% (72.0ϕx74.8mm,271cm^3)	2.51
E	well (21mmϕx66mm)	71% (74.0ϕx80mm,310cm^3)	1.63
F	well (21mmϕx62mm)	56% (70.0ϕx75mm,252cm^3)	1.88
S	well (21mmϕx66.5mm)	56% (71.7ϕx74.8mm,260cm^3)	5.45
A	well (21mmϕx62.5mm)	56% (72.0ϕx75.0mm,272cm^3)	2
B	well (21mmϕx62.5mm)	56% (72.0ϕx74.7mm,272cm^3)	1.93
H	well (21mmϕx66.5mm)	71.7% (74.0ϕx80mm,309cm^3)	2.09
W	well (21mmϕx60mm)	65% (75.1ϕx81mm,344cm^3)	1.72
X	well (21mmϕx68mm)	73.4% (74.3ϕx80mm,311cm^3)	1.69
Y	well (21mmϕx68mm)	70.5% (74.3ϕx80mm,314cm^3)	1.4
Z	well (16mmϕx62mm)	51.5% (67.6ϕx70mm,231cm^3)	1.5
U	coaxial	94% (78.9ϕx81mm,379cm^3)	1.12
αβ	LSC	20cm^3	

BG: integrated count rate (50–2000 keV)

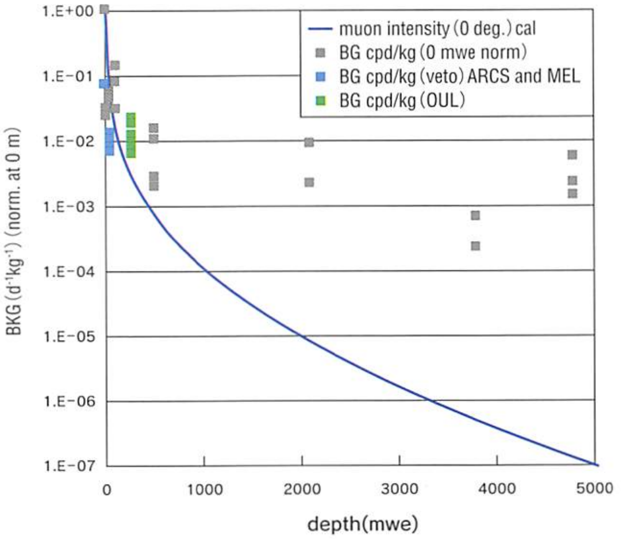

Fig. 2 The muon intensity expected underground and the background count rates listed in Table 1 (normalized to aboveground values).

Historical dates within OUL

Some significant measurements have been made at OUL such as the detection of low level cosmogenic nuclides, natural radionuclides, fission products and activated nuclides induced by environmental neutrons and fission neutrons. Historical dates in OUL's operation are summarized in Table 3.

Table 3. Historical dates in OUL

1995	Measurements of cosmic ray-induced nuclides of the "Neagari Meteorite" which fell on Feb. 18 at Neageri, Ishikawa. These were the first measurements made at OUL, and they were used to estimate the orbit of the meteorite and its condition during the fall.
1996	Measurements of cosmic ray-induced nuclides of the "Tsukuba Meteorite (5 Fragments)" which fell on Jan. 7 at Tsukuba, Ibaraki, and estimation of its orbit and condition during the fall.
1997	Measurements of ^{137}Cs and ^{134}Cs that leaked from the bituminization facility of the Power Reactor and Nuclear Fuel Development Corporation by an explosion accident on March 11. This included analysis of the radioactivity plume over several days after the accident in collaboration with Meteorological Research Institute.
1998-2000	Identification of about 20 nuclides, such as ^{24}Na, ^{46}Sc, ^{60}Co, ^{76}As, ^{134}Cs, ^{152}Eu, ^{192}Ir, and ^{198}Au induced by environmental neutrons derived from cosmic rays.
1999	Measurements of cosmic ray-induced nuclides of the "Kobe Meteorite" which fell on Sept. 26 at Kobe, Hyogo (identification of ^{28}Mg, ^{57}Ni, etc.), and estimation of its orbit and condition during the fall.
	Environmental impact assessment and investigation of the criticality accident at JCO, Tokai-mura, Ibaraki on Sept. 30 as part of a surveillance study group. This was marked by publication of the first special issue on the criticality accident in *Journal of Environmental Radioactivity* (Elsevier); 5 of 21 papers were from studies made at OUL.
2001-2002	Measurements of the neutron-induced nuclide ^{152}Eu. These contributed to a solution of the discrepancy between measured and calculated values that has been discussed during the past two decades, and to the decision to introduce a new dosimetry system, the DS02, for measurements of atomic bomb radiation.
2003	High temporal resolution measurements of airborne ^{210}Pb and ^{7}Be.
2004	Simultaneous detection of short lived cosmic ray-induced ^{18}F, ^{24}Na, ^{28}Mg (^{28}Al), ^{38}Cl (^{38}S), ^{39}Cl, ^{7}Be, and ^{22}Na in rain water.
	Analysis of the residence time of Lake Biwa water by cosmic ray-induced ^{22}Na as a tracer.
2005	Identification of the highly sensitive nuclide ^{108m}Ag induced by atomic bomb neutrons at Hiroshima and Nagasaki.
2006	Identification of seasonal variations of the Ra isotope ratio ($^{228}Ra/^{226}Ra$) in coastal water and sea weeds in the Sea of Japan.
	Analysis of depth profiles of environmental neutron flux and environmental neutron transport in sea water, fresh water, concrete, iron, and lead.
2007	Utilization of radiometric dating by ^{228}Th / ^{228}Ra ratio in bone and crustacean
2007-2009	Depth profiles of ^{137}Cs in deep sea water of the Pacific Ocean.

Collaborations

- Research on "**Distribution and Transportation of Artificial Radioactive Nuclides in Sea Water**" for a long time range and wide area. (Participants are: Marine Ecology Research Institute, Meteorological Research Institute, National Institute of Radiological Sciences, Electric Power Industry, IAEA - Marine Environmental Laboratory, and University of Bratislava.)
  - ► Measurement of time-dependent and three-dimensional distributions of radioactive nuclides, and biological concentrations in the geosphere, the hydrosphere (the oceans), the atmosphere, and the biosphere for the Asian Area.
  - ► Experimental elucidation of ocean circulation and the "thermohaline circulation" process as related to climate changes and global warming.
  - ► Contributions to updating and merging two databases, Historical Artificial Radionuclides in the Pacific Ocean and Its Marginal Seas (HAM database) of Meteorological Research Institute and Marine Information System (MARIS) of IAEA, and to expanding data to all oceans through SHOTS project (Southern Hemisphere Ocean Tracer Studies).
  - ► Construction of diffusion and transportation models of radioactive nuclides released into the marine environment.

- Research on "**Radionuclides from the Sun - Measurement of Radionuclides from the Sun implanted on Genesis Mo-Pt foils**". (NASA project (2008-2010) carried out with the University of California.)
  - ► Measurements of radioactive nuclides implanted into Mo-Pt foils, which were exposed to solar wind at spacecraft.
  - ► Estimation of atomic composition in the primordial solar system.

- Measurements of the nuclear reaction cross sections bombarded by high energy neutrons (Participants are the University of California and Osaka University.)
  - ► Investigation of nucleosynthesis by neutron capture in a supernova explosion.

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