ITA/AITES

TRAINING MATERIAL

CIVIL REUSES OF UNDERGROUND MINE VOIDS

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Introduction

When mining operations are discontinued, a large and potentially usable space is left behind.

Many examples of civil reuses of former mine openings exist through-out the world.

The main types of reuses have been divided into four categories:

1. Mining museums
2. Civil applications and goods storage
3. Waste disposal
4. Experimental laboratories and research facilities

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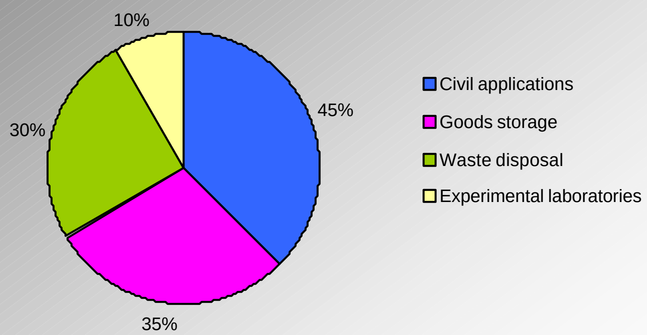
Introduction

The possibilities for reuse of the space obtained after mining activity ends, or during the development of mining operations, are of great interest for a number of reasons:

1. The economic value of the space offers great potential for the mining industry, in that some "marginal" orebody may become exploitable when the economic value of the derived underground space is factored into the planning considerations.
2. The mine openings can be a significant resource when surface space is at a premium, as is the case, for example, in Japan and in many other highly developed urban areas.
3. In some cases, large-scale development of space in former mines can take advantage of the potential reductions in construction and energy costs.
4. Some quarries associated with environmental problems may be transferred safely to the underground and still be profitable.
5. Some industrial or polluting activities, such as industrial waste storage, can be transferred to abandoned mined space in order to reduce their impact on the surface environment.

Introduction

This graph shows the percentage distribution of the various applications from data collected by ITA/AITES W.G. 4 “Use of Underground Space” in 1994 (the reuse as museums where non considered)



Reuse as mine museum

Wieliczka mine museum - Salt mine (Poland)
(http:// auger.ifj.edu.pl)

Reuse as mine museum

Wieliczka mine museum - Salt mine (Poland)

(http://www.cyf-kr.edu.pl)

Reuse as mine museum

Wieliczka mine museum - Salt mine (Poland)

(http://www.efort.pl)

Reuse as mine museum

Mine museum and underground turistic tour- Talc mine (Prali, Italy)

(http://www.scopriminiera.it)

Reuse as mine museum

Mine museum and underground turistic tour- Talc mine (Prali, Italy)

(http://www.scopriminiera.it)

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Reuse for civil application

Reused mined space can be converted to a number of civil uses. Advantages of subsurface space use such as noise protection, environmental isolation, a vibration-free atmosphere, energy conservation characteristics, security, in addition to preservation of the surface environment, are associated with these civil applications.

The most important mines civil reuses are listed in the following tables:

- Rooms for aging of cheese and wine
- Hospitals
- Laboratories
- Offices
- Conference rooms
- Mushroom farms
- Sports facilities
- Factories

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Reuse for civil application

The isolating and vibration-free environment and security provided by subsurface space developments lends itself to many reuses of mines for storage purposes.
The most important mines civil reuses are listed in the following tables:

- Storage of oil, water and agricultural products
- Archives
- Warehouse facilities
- Car and boat storage facilities

Reuse for civil application

Country	Name of Mine	Type of Ore	Type of Reuse	Notes
Canada	Wabana mine (Bennet-Smith and Mitlis 1977)	Iron	Storage of crude oil.	Concept under study in 1977.
Finland	Outokumpu mine (Pelizza 1978)	Polymetallic sulphides	Compressed air.	
France	Abandoned mines (Duffaut 1992)	Building stones	Mine storages and cheese aging; mushroom growing; exhibition halls; museums.	Room and pillar.
	May-Sur-Orne mine (Maury 1977)	Iron	Storage of oil (5,000,000 m^3)	Exploitation at full stope, with some pillars left as roof support.
	Mendon mines (Souffaché and Viré 1987)	Limestone and construction materials	Industrial activities and mine museum (under study); mushroom farming (since 1960).	Room and pillar. Quarries exploited since the 18th century.
Hungary	Budapest-area mines (Mullen 1991)	Limestone	Storage of wine or beer and cheese aging.	Room and pillar.
	Eger-area mines (Muller 1991)	Rhiolite tuff	Pubs; storage of wine; museums of wine-making procedures.	Room and pillar.
	Fertorakos mine (Mullen 1991)	Limestone	Theatre.	Room and pillar.
Italy	Cogne mine	Iron	Tourist railway transport between two adjacent mountain valleys. Mine museum	Mine tunnels.
	Santa Brigida mine (Pelizza 1978)	Chalk	Mushroom growing.	Room and pillar.
	Ollomont mine (Mathiou 1986)	Copper	Cheese aging.	Old mine tunnel.
	San Leone mine	Iron	Storage of wine.	
	Traversella mine (Lazzari et al. 1991)	Iron	Mine museum and laboratories for tests on drilling equipment, on rock mechanics monitoring devices and on explosives.	Concept under study in 1991.
Japan	Ohya mine (Carmody and Sterling 1993)	Building stone	Industrial uses, food storage, art exhibitions.	Room and pillar.
	Kamasaishi mine (JTA 1991;Takasaki 1991)		Various laboratories for tests on explosives, on drilling equipment, and on rock mechanics monitoring devices.	Caverns with width and length of about 100 m and with a variable height.
Netherlands	Valkenburg ore mines (Maurenbrecher 1991)	Limestone	Tourism.	Room and pillar. Exploitation began in prehistoric times. Some quarries are still being exploited.
Poland	Wieliczka mine (Tekst and Zdjiecia 1988)	Salt	Mine museum; sports facilities; hospital for lung diseases.	Mines exploited since the Middle Ages. Room and pillar.

Tables from Pelizza and Peila, 1995

Reuse for civil application

Country	Name of Mine	Type of Ore	Type of Reuse	Notes
Romania	Slanic Prahova mine (Fodor 1994)	Salt	Hospital for lung diseases.	Room and pillar.
Russia	Berezniki-I mine (West Urals - Verkhnekamsoye salt and potash deposit) (Papulov and Fainburg 1994)	Potash	Hospital for lung diseases.	Room and pillar. The hospital was built in 1975.
	Berezniki-I mine (West Urals - Verkhnekamsoye salt potash deposit) (Papulov and Fainburg 1994)	Potash	Hospital for lung diseases; sports facilities.	The structure was especially built, with the ore extracted as a by-product. A 4 km long tunnel was especially built as an air preparation system.
	Verkhnekamsoye area mines (Papulov and Fainburg 1994)	Potash	Mushroom growing.	Room and pillar.
	Verkhnekamsoye- area mines (Paputov and Fainburg 1994)	Potash	Storage of food and agricultural products.	Room and pillar. Under study and development.
Slovenia	Senovo mine (Scukanec 1994)	Coal	Drinking water source.	
Sweden	Dannemora mine (Nordmark 1991)	Iron	Educational purposes: training activities for mining and tunnelling machine operators.	Sublevel caving.
	Harsbacka mine (Winqvist and Mellgren 1988)	Fluorite	Storage of oil (1,000,000 m^3).	Large void. The mine was converted in 1948 and is still in operation.
	Ljunsnarberg mine (Nordmark 1991)	Sulfide	Storage of hot water (265,000 m^3 reused).	Pilot project by the Swedish Council for Building Research.
	Kirunavaara mine (Nordrmark 1991)	Iron	Mushroom growing.	
	Kvamtorp mine (Nordmark 1991)	Sandstone	Archives, conference rooms	Room and pillar.
United Kingdom	Liechwedd slate mine	Coal	Tourism.	
United States	Kellogg mine (Idaho) (Canmody and Sterling 1993)	Pb-Zn	Seedlings grown under artificial light.	
	Butte mine (Montana) (Carmody and Sterling 1993)	Copper	Seedlings grown under artificial light.	
	Crested Butte mine (Colorado) Carmody and Sterling 1993)	Molybdenum	Seedlings grown under artificial light.	
	Randolph mine (Missouri) {Steam 1965)	Limestone	Steel company plant for manufacturing conveyors and tanks. Concrete pipe manufacture. Storage of goods.	Room and pillar.
	Pixley Co. mine (Misouri) (Steam 1965)	Limestone	Construction of sailing crafts made of fiberglass-reinforced plastic.	Room and pillar.

Tables from Pelizza and Peila, 1995

Reuse for civil application

Country	Name of Mine	Type of Ore	Type of Reuse	Notes
United States	Zenith mine (Minnesota) (Leoni 1985)	Iron	Mine used as a heat source.	Concept under study. Sublevel caving.
	Kansas City-area mines (Missouri-Kansas) (Woodard 1980; Kjelshus 1984; Sterling and Circo 1984; Carmody and Sterling 1993)	Limestone	Offices/warehousing space/ manufacturing. 23 million m^2 excavated thus far; 2.3 million m^2 reused. Storage of various product.	Room and pillar. The quarries are still excavated to obtain underground openings. 7-70 m overburden.
	Boyce limestone mines (Pennsylvania) {Bennet-Smith and Millis 1977)	Limestone	Offices. 300 employees work underground. 45,000 m^3 reused.	Room and pillar. Flat-lying formation, 6 m thick (Vanport formation). 50-70 m overburden.
	Louisville Crushed Stone Company mine (Kentucky) (Ullrich et al. 1984)	Limestone	Commercial and industrial uses.	Room and pillar.
	Springfield mine (Missouri) (Underground Space Center archive 1991)	Iron	Food storage.	Cavern and mine tunnel.
	Iron Mountain mine (New York state) (Davies and Willet 1977; Bennet-Smith and Millis 1977)	Iron	Storage of computer tapes, microfilm and movies.	Reused mine drifts.
	Rosendale-area mines (Bennet-Smith and Millis 1977)	Limestone	Storage of records; mushroom farming.	Room and pillar (66,000 m^3 reused). Flat-lying formation 7 m thick; 50 m overburden.
	Cote Blanche mine (Louisiana) (Davies and Willet 1977; Kelsall et al. 1980)	Salt	Storage of crude oil (27 M bbl)	Concept under study in 1980. Room and pillar.
	Western Pennsylvania limestone mines (Pennsylvania) (Bennet-Smith and Millis 1977; Underground Space Center archive 1991)	Limestone	At New-Castle: deposit of cars and pleasure boats. Wampum mine storage company: storage of goods, document, offices, concrete testing laboratory and industrial installations (300,000 m^3 reused).	Room and pillar. Flat-lying formation 6 m thick (Vanport formation). 50-70 m overburden.
	Central Rock mine (Kentucky) (Kelsall et al. 1980)	Limestone	Storage of crude oil (14 M bbl)	Concept under study in 1980. 80 m overburden.
	Ironton mine (Ohio) (Davies and Willet 1977; Kelsall et al. 1980)	Limestone	Storage of crude oil (21 M bbl)	Concept under study in 1980. Room and pillar.
	Zero Mountain mine (Arkansas) (Stearn 1995)	Limestone	Frozen food storage facility	Room and pillar.
	Southwest Lime mine (Missouri) (Steam 1995)	Limestone	Frozen food storage facility	Room and pillar
	Lime Field mine (New York state) (Underground Space Center archive) 1991	Limestone	Storage of crude oil	Room and pillar.

Tables from Pelizza and Peila, 1995

Reuse for civil application

Mushroom growing - room and pillar mine (Italy)

(Pelizza and Peila, 1995)

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Reuse for civil application

Mushroom growing - room and pillar mine (Italy)

(Pelizza and Peila, 1995)

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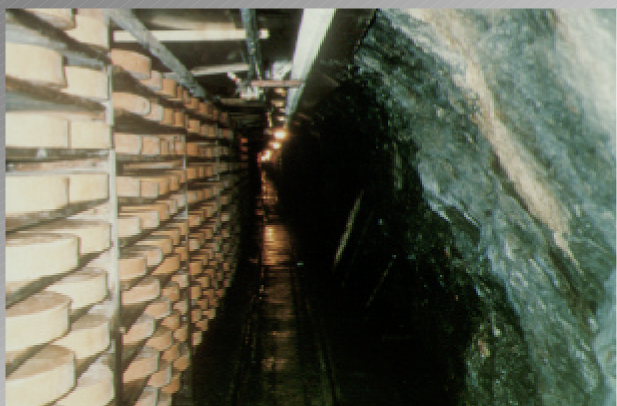
Reuse for civil application



Cheese ageing – Iron mine tunnel (Aosta valley, Italy)

(Pelizza and Peila, 1995)

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Reuse for civil application

Underground cantine - Room and pillar mine

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Reuse for civil application

Kansas City (USA)

The most famous, and certainly most extensive, reuse of mined space has taken place in Kansas City, Missouri (U.S.A.), where underground space is a by-product of a mining operation. Thanks in large part to the geology of the region, developers have succeeded in using mined space in the area for secondary uses while continuing to reap profits from mining the limestone for road-base materials and aggregate products. The usable space created by the mining operations is secondary to the mining itself.
Beginning in the 1960s, Kansas City's mined space has been converted, at a rate of approximately 9000 m^2 annually, into facilities for warehousing, manufacturing, offices, retail and service operations. Of the 23 million m^2 of space mined to date, more than 2.3 million m^2 has been developed for such secondary use purposes; approximately 5.6 million m^2 is available for immediate development; and 0.5 million m^2 is added each year to the inventory of developable space.

Reuse for civil application

Good storages and offices - Room and pillar limestone quarry
Kansas City (USA)

(http://www.huntmidwest.com)

Reuse for civil application

Good storages and offices - Room and pillar limestone quarry
Kansas City (USA)

(photo - courtesy Prof. S.Pelizza)

Reuse for civil application

Good storages and offices - Room and pillar limestone quarry
Kansas City (USA)

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Reuse for civil application

Good storages and offices - Room and pillar limestone quarry
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Reuse for civil application

Good storages and offices
Room and pillar limestone quarry
Kansas City (USA)

(photos - courtesy Dr. S. Nelson)

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Reuse for civil application

Good storages and offices - Room and pillar limestone quarry
Kansas City (USA)

(photo - courtesy Dr. S. Nelson)

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Reuse for waste disposal

Mines reused for Disposal of Wastes

Burying non-nuclear industrial waste and radioactive waste under-ground is a fairly recent concept, but one that has attracted considerable interest in the past twenty years.

Salt mines, which normally are excavated by the room-and-pillar method, are of great interest in view of the possibility of reusing the openings for waste disposal.

Environmental concerns with protecting the biosphere, coupled with in-creasing amounts of such wastes, undoubtedly will lead to further consideration of this type of reuse of existing abandoned mined space (ITA 1994).

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Reuse for waste disposal

Country	Name of Mine	Type of Ore	Type of Reuse	Notes
Australia	Burwood Beach mine Newcastle colliery (McMahon 1993)	Coal	Sludge disposal	Longwall mining. Concept studied and abandoned.
France	Joseph-Else mine (Stocamine 1991)	Potash	Storage of industrial wastes.	Concept under study. Room and pillar. The stockage area is below the exploited level of the mine (at 900 m depth).
Germany	Asse mine (GSF 1990; Franklin and Dusseault 1991)	Potash and salt	Storage of radioactive wastes. Tests for radioactive waste storage.	Room and pillar (depth of 490-830 m). Since 1967, low-level wastes have been emplaced for experimental purposes. Storage of intermediate-level wastes in a former room from an upper level (depth of 511 m).
	Bartensleben mine (Franklin and Dusseault 1991)	Salt	Storage or radioactive wastes. Tests for radioactive waste storage	
	Konrad mine (DBE 1994)	Iron	Storage of radioactive wastes. Tests for radioactive waste storage.	Ore mining performed from 1965 to 1976. The mine has a good impermeability to ground water due to the predominantly clayish overlying strata (depth of 800-1300 m). Concept under study in 1994.
	Heilbronn mine (Wegener 1993; UEVa 1994)	Salt	Storage of fly-ash wastes; storage of anhydrite and clay contaminated with Hg.	Room and pillar. Rooms are 15 m wide, 10-20 m high and 200 m long; pillars are 15-17 m wide. Depth 200 m.
	Kochendorf salt mine (UEV 1994b)	Salt	Storage of flue-gas, desulfurization residue from incineration plants and siliceous slags.	Room and pillar. The rooms are filled by alternating strata made of bags with the residues and waste salt.Concept under study in 1994.
	Walsum mine (Northrhine-Westfalia coal colliery (DMT 1991; Stringel 1993)	Coal	Storage of fly-ash from incineration plants in the goaf.	Concept under study in 1993. Longwall mining.Concept under study in 1993.
	Wintershall mine UTD Herfa-Neurode storage deposit (Schneider 1992; Wegener 1993; Kali uns salz Beteiligungs A.G. 1994)	Potash	Storage of wastes (fly ash from incinerator plants account for the largest amount of the stored waste).	Room and pillar. Begun in 1972 in an abandoned section of Wintershall mine.

Tables from Pelizza and Peila, 1995

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Reuse for waste disposal

Country	Name of Mine	Type of Ore	Type of Reuse	Notes
India	Korba colliery mines (Ghosh 1990)	Coal	Storage of industrial wastes.	Concept under study.
Italy	Codana mine (Giani 1988; Pelizza 1992)	Gypsum	Storage of industrial wastes.	Room and pillar.
	Besta mine (De Carli 1991)	Dolomite	Storage of inert debris (36,000 m^3 reused).	Room and pillar.
Japan	Nakatatsu mine (Uchino 1994).	Pb-Zn-Ag	Storage of fly-ash from incineration plants.	The ash is mixed with soil and stored in an abandoned tunnel; 12,000 m^3 stored since 1991.
	Shin-Yakuki mine (Uchino 1994)	Limestone.	The goaf in limestone is utilized for disposal of fly-ash from coal-burning power station.	Sublevel stoping.
Russia	Verkhnekamsoye-area mines (Papulov and Fainburg 1994)	Potash	Storage of waste.	Room and pillar. The rooms are backfilled with waste.
Slovenia	Velenje mine (Bajzelj et al. 1994)	Coal	Storage of fly-ash.	Longwall mining.
United Kingdom	Walsall Wood colliery old mine (Franklin and Dusseault 1991)	Coal	Storage of chemical wastes.	The 900 m deep mine is environmentally isolated by a geological graben with clay-filled faults at either side and by layers of shales above. Storage of wastes began i
	Dudley mines (Brook 1987).	Limestone	Colliery waste and fly-ash pumped in the voids from the surface.	Room and pillar. The collapse of many rooms caused instability of the surface. The waste disposal permitted the mine to obtain stability.

Tables from Pelizza and Peila, 1995

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Reuse for waste disposal

Heilbronn salt mine (Germany)

Up to now mining created a volume of more than 45 million m³ cavities underground in Heilbronn and Kochendorf.

Those cavities represent valuable resources that are used for waste disposal by high safety standards for years.

Approximately 500 waste types of materials are authorised for the underground waste repository.

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Reuse for waste disposal

Heilbronn mine waste storage - Salt mine Germany)

(http://www.uev.de)

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Reuse for waste disposal

Heilbronn mine waste storage - Salt mine Germany)

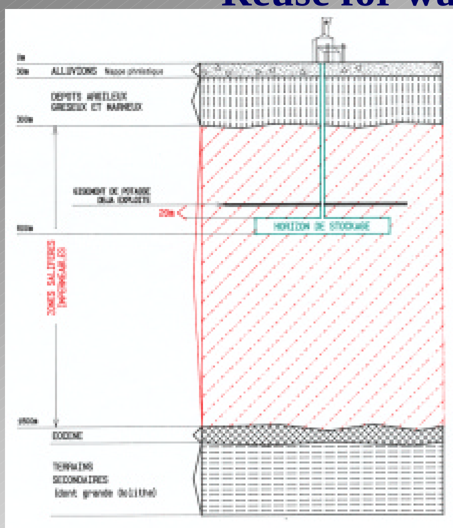
(http://www.uev.de)

Reuse for waste disposal

UTD Herfa-Neurode storage deposit - Potash mine (Wintershall, Germany)

(http://www.k-plus-s.com)

Reuse for waste disposal



Joseph-Else mine -industrial wastes storage (Alsace, France)

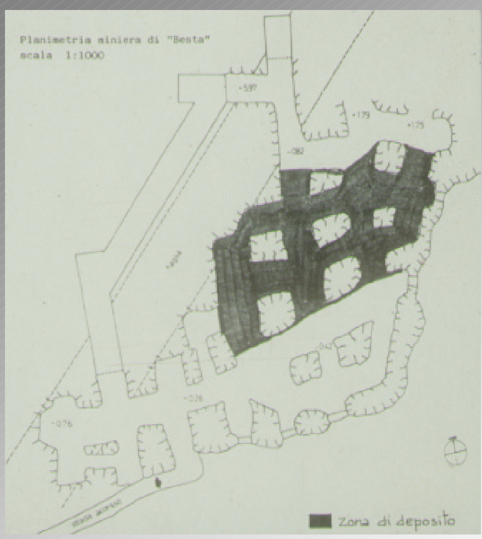
(http://www.stocamine.com)

Reuse for waste disposal

Joseph-Else mine non-radioactive industrial wastes storage (Alsace, France)

(http://www.stocamine.com)

Reuse for waste disposal



Besta mine waste storage (Italy)

(De Carli, 1991)

In the mine are stored the wastes which come from the demolition of the surface buildings of the mine.

Reuse for waste disposal

Besta mine waste storage (Italy)

(De Carli, 1991)

Conclusions and references

The room-and-pillar method of mining has been used in the greatest number of mine reuse projects.

This type of mining is particularly applicable to secondary reuses because:

- The geometry of the previously constructed rooms usually is readily adaptable to reuses, without requiring much additional preparation work;
- It is relatively easy to evaluate the safety factors related to the support pillars;
- The quality of the rock mass normally is good when this method has been applied.

Quarries that raise environmental concerns when located on the surface can be transferred underground and still be profitable even when a low-value ore is mined, provided that the increased mining costs can be balanced by the value of the underground space and by the reduction in the amount of environmental restoration required when the mine exploitation for ore has ended.

Conclusions and references

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Conclusions and references

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