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PRACTICAL APPLICATION OF THE UNITED NATIONS INTERNATIONAL FRAMEWORK CLASSIFICATION FOR RESERVES/RESOURCES

Application of the UN International Framework Classification to mineral resource estimates in Finland

(Submitted by the Government of Finland) *

1. Introduction

Three cases will be studied here. Two of the targets are real mineral deposits originally localized and evaluated by the Geological Survey of Finland (GTK). First one is the *Keivitsa disseminated sulfide occurrence* with semi-economic (or intrinsic) amounts of nickel, copper, gold and platinum group metals. Second one is the *Pahtavaara Gold Deposit*, currently mined by Terra Mining Oy. Third one is an imaginary *"Goldhole Deposit"* with features typical to many Finnish gold occurrences. It functions as an application basis for prospect (occurrence to deposit) evaluation. *The Saattopora Gold Deposit* case will be treated as soon as data become available in a doctoral thesis that will be published shortly.

For Pahtavaara material we thank Terra Mining Oy.

* Prepared by Mr. Jyrki Parkkinen, Geological Survey of Finland.

2. Examples of the work at the Geological Survey of Finland (GTK)

GTK is involved in mineral exploration from regional- to prospect-scale projects. GTK acquires sufficient data for prospects to encourage further evaluation by the private sector. All discoveries and prospects are tendered to the private sector either fully or on a joint-venture basis through the Ministry of Trade and Industry. Prospect scale here covers Prospecting and General Exploration. For tendering all discovered occurrences are classified and evaluated. An exceptionally densely drilled target, the Keivitsa Ni-Cu-PGE Occurrence serves here as an example. Another example, Goldhole Deposit, is a demonstration with instructions for prospect evaluation.

2.1 The Keivitsa Ni-Cu-PGE-Au Occurrence

The Keivitsa Occurrence is located inside the Keivitsa layered intrusion. The disseminated sulfidic mineralization does not seem to follow the layered structures but it is like a cloud with no apparent structurally controlled enrichments although several subtypes with different mineral associations exist. It is a low-grade occurrence with nickel averaging 0.2 to 0.3 % (cutoff grades 0.1 or 0.2 % Ni), copper averaging from 0.25 to 0.5 %, platinum averaging from 0.1 to 0.5 g/t and gold averaging 0.06 to 0.15 g/t.

The three different resource estimates below (Fig. 1) were all based on similar drill core data but techniques for estimates were different. The (333) estimate is a "bulk estimate" where the Ni bearing occurrence was roughly outlined to the extreme depth given by deepest drill holes. On the other hand, the (322) estimate was done carefully considering lithologic and grade continuities and discontinuities to the depth of 100 m which was reached by practically all drill holes. Sampling density was the primary criterion for classification along with cutoff grades of 0.1 % and 0.2 % for nickel.

A. The Keivitsa Ni-Cu-PGE occurrence

UN International Framework		Detailed Exploration Mt	General Exploration Mt	Prospecting Mt	Reconnaissance Mt
	National System	Detailed Exploration	General Exploration	Prospecting	Reconnaissance
Feasibility Study or Mining Report	Ore Reserve, Proved				
Prefeasibility Study	Ore Reserve, Probable Min. Resource, Measured Min. Resource, Indicated				
Geological Study	Min. Resource, Measured Min. Resource, Indicated Min.Resource, Inferred	(322) 30 / 10 (*	(332) 112 / 35 (*	(333) 450 (*	

*) - to the depth of 100 m - cutoff 0.1 / 0.2 % Ni
*) - to the depth of 300 m - cutoff 0.1 / 0.2 % Ni
*) - to the depth of 850 m - cutoff grade 0.1 % Ni

Figure 1.
Resource estimates based on same samples but on different estimation techniques of the Keivitsa Ni-Cu-PGE-Au Occurrence. (333) includes (332) that includes (322). The estimates are thus inclusive and non-additive.

The classification table demonstrates how estimates may broadly vary. Acknowledging sample density along with a more cautious or realistic approach to beneficiation tightens estimation criteria while resource volume decreases and geological assurance increases. In this case both extra drilling and process mineralogical investigations should be done to develop the occurrence for a prefeasibility study.

2.2 The (imaginary) Goldhole Prospect: Development from an occurrence to a deposit

The Goldhole Occurrence was located during a prospecting phase of exploration in a gold potential zone outlined during the preceding reconnaissance. Preliminary geological information of the site and probable analogies indicated that the occurrence might size 1 to 10 Mt and it might contain 5 to 10 g/t gold (Fig. 2). To conduct further exploration two different economic scenarios were constructed based on analogies and on general knowledge of the beneficiation of gold deposits (Fig. 3).

During general exploration the occurrence was recognized as a deposit with a minimum volume of 0.8 Mt and averaging 6.4 g/t gold (Fig. 2). The deposit consisted of several subvertical pipes which were outlined to a depth of 100 m. Two scenarios were made, one with the lowest long time market price for gold (8.5 EUR/g) and the other with a higher expected future price (11 EUR/g). However, the deposit seemed too small for beneficiation (Fig. 4). Therefore a third scenario was constructed with a volume of 1.5 Mt which seemed to make the deposit economically interesting. For the next investigation phase, detailed exploration, a goal was stated: volume must be enlarged to further develop the deposit.

During detailed exploration one more pipe was delineated and also the continuation of some other pipes to a depth of 200 m was confirmed. A result 2.2 Mt with 5.2 g/t gold was estimated to be indicated resource of the Deposit. Laboratory tests revealed that a gold recovery of 92 % could be reached by successive gravimetric and flotation enrichment. A separate Cu concentrate can be prepared. Again, two scenarios with low and high gold prices were created. In this phase they were called a Prefeasibility Study. It appeared that the Goldhole Prospect is potentially economic at expected gold prices above 8.5 EUR/g.

The Goldhole Gold Prospect

UN International Framework		Detailed Exploration Mt	General Exploration Mt	Prospecting Mt	Reconnaissance Mt
	National System	Detailed Exploration	General Exploration	Prospecting	Reconnaissance
Feasibility Study or Mining Report	Ore Reserve, Proved				
Prefeasibility Study	Ore Reserve, Probable Min. Resource, Measure Min. Resource, Indicatec	(222) 2.2 (*			
Geological Study	Min. Resource, Measure Min. Resource, Indicatec Min.Resource, Inferred		(322) 0.8 (*	(333) 1 - 10 (*	
		*) 5.4 g/t Au	*) 6.4 g/t Au	*) 5 - 8 g/t Au	

Figure 2.
Resource estimates for the Goldhole Prospect at different successive phases of exploration. The estimates at different exploration stages are non-inclusive (mutually exclusive: 222 is an improvement of 322 which is an improvement of 333. The estimates are also non-additive.

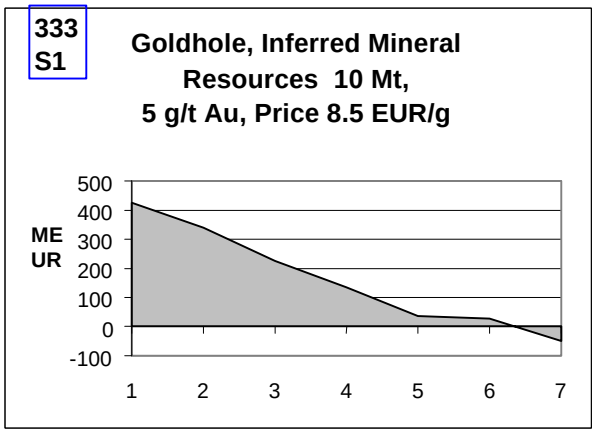
GOLDHOLE: Prospecting, Geological Study, Intrinsic Economic Interest

Mineral resources are inferred. The Goldhole Occurrence is located in an area or zone known to be potential for gold. Expected deposits may have sizes 1 - 10 Mt and assaying 5 - 10 g/t of gold. Price of gold is expected to be 8.5 - 11 EUR/g.
All estimates are "in situ" or based on general experience, analogies and expectations. No conclusions about the profitability of mining can be drawn, but only estimates on the "opportunity value" of the two deposit types outlined below.
"Deposit value" is the estimated value to investors when all costs have been reduced.

UNCODE 333.00

Scenario 1. Big deposit, low grade, gold price 0.85 EUR/g:			**Deposit**	**Remarks**	
Volume	10	Mt	**Value**		EUR/g
Average grade	5	g/t	**MEUR**	Au	8.50
Open pit mining (60 %) and underground (40%)	Costs/Losses				
"In situ value"			**425.00**		
Recovery to concentrates 80 %	20	%	**340.00**	Ore loss & dilution	
- mine construction + development + interests	115	MEUR	**225.00**	Plant, infra, equipment	
- operation costs, open pit 60.00%	15	EUR/t	**135.00**	Mining, dressing, transport	
- operation costs, underground 40.00%	25	EUR/t	**35.00**	Mining, dressing, transport	
- exploration + investigations	7	MEUR	**28.00**	Drilling, field work, geology	
General overheads + security margin: 25%+15%	40	%	**-50.80**		
Profit before tax			**-50.80**		

Scenario 2. Small deposit, high grade, gold price 11 EUR/g:			**Deposit**	**Remarks**	
Volume	1	Mt	**Value**		EUR/g
Average grade	8	g/t	**MEUR**	Au	11.00
Open pit mining	Costs/Losses				
"In situ value"			**88.00**		
Recovery to concentrates 80 %	20	%	**70.40**	Ore loss & dilution	
- mine construction + development + interests	20	MEUR	**50.40**	Plant, infra, equipment	
- operation costs, open pit 1.00	15	EUR/t	**35.40**	Mining, dressing, transport	
- operation costs, underground 0.00	0	EUR/t	**35.40**	Mining, dressing, transport	
- exploration + investigations	7	MEUR	**28.40**	Drilling, field work, geology	
General overheads + security margin: 25%+15%	40	%	**19.60**		
Profit before tax			**19.60**		



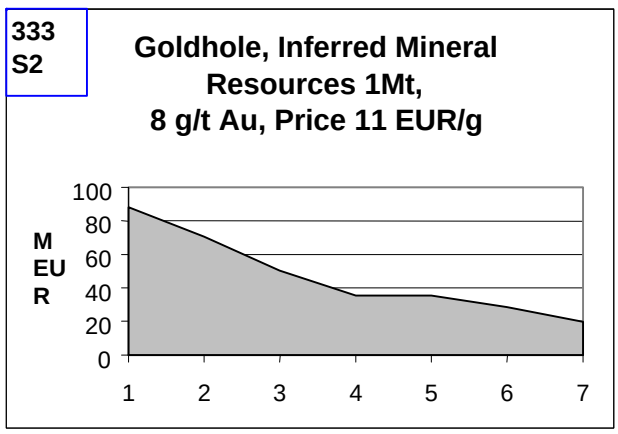


Figure 3. Evaluation of Goldhole Prospect on base of prospecting phase of exploration. Observe the "value of deposit" stepwise (steps 1 to 7) reduced.

GOLDHOLE: General Exploration, Geological Study, Intrinsic Economic Interest

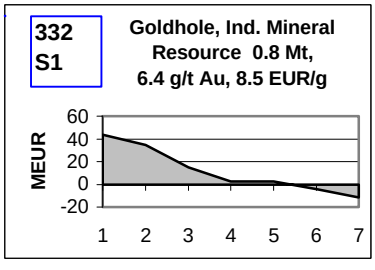
The Goldhole deposit has been located and geologically outlined to the depth of 100 m. Deposit shape, size and averaged grade can be calculated. Therefore the first Mineral Resource Estimate based on real observations (indicated resources) can be made. According to it Goldhole's gold grade comes close to the grade of Scenario 1 (5 g/t) and size comes close to the size in Scenario 2 (1 Mt) The two scenarios are updated and a third scenario for a bigger deposit will be outlined.

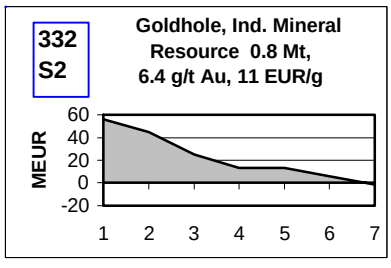
UNCODE 332

Scenario 1. Small deposit, low grade, gold price 8.5 EUR/g:			**Deposit**	**Remarks**
Volume	0.8	Mt	**Value**	EUR/g
Average grade	6.4	g/t	**MEUR**	Au 8.50
Open pit mining (60 %) and underground (40%)	Costs/Losses			
"In situ value"			**43.52**	
Recovery to concentrates 80 %	20	%	**34.82**	Ore loss & dilution
- mine construction + development + interests	20	MEUR	**14.82**	Plant, infra, equipment
- operation costs, open pit 1.00	15	EUR/t	**2.82**	Mining, dressing, transport
- operation costs, underground 0.00	0	EUR/t	**2.82**	Mining, dressing, transport
- exploration + investigations	7	MEUR	**-4.18**	Drilling, field work, geology
General overheads + security margin: 25%+15%	40	%	**-11.78**	
Profit before tax			**-11.78**	

Scenario 2. Small deposit, low grade, gold price 11 EUR/g:			**Deposit**	**Remarks**
Volume	0.8	Mt	**Value**	EUR/g
Average grade	6.4	g/t	**MEUR**	Au 11.00
Open pit mining (60 %) and underground (40%)	Costs/Losses			
"In situ value"			**56.32**	
Recovery to concentrates 80 %	20	%	**45.06**	Ore loss & dilution
- mine construction + development + interests	20	MEUR	**25.06**	Plant, infra, equipment
- operation costs, open pit 1.00	15	EUR/t	**13.06**	Mining, dressing, transport
- operation costs, underground 0.00	0	EUR/t	**13.06**	Mining, dressing, transport
- exploration + investigations	7	MEUR	**6.06**	Drilling, field work, geology
General overheads + security margin: 25%+15%	40	%	**-1.54**	
Profit before tax			**-1.54**	

Scenario 3. Medium size deposit, low grade, gold price 11 EUR/g:			**Deposit**	**Remarks**
Volume	1.5	Mt	**Value**	EUR/g
Average grade	6.4	g/t	**MEUR**	Au 11.00
Open pit mining (60 %) and underground (40%)	Costs/Losses			
"In situ value"			**105.60**	
Recovery to concentrates 80 %	20	%	**84.48**	Ore loss & dilution
- mine construction + development + interests	20	MEUR	**64.48**	Plant, infra, equipment
- operation costs, open pit 1.00	15	EUR/t	**41.98**	Mining, dressing, transport
- operation costs, underground 0.00	0	EUR/t	**41.98**	Mining, dressing, transport
- exploration + investigations	7	MEUR	**34.98**	Drilling, field work, geology
General overheads + security margin: 25%+15%	40	%	**23.18**	
Profit before tax			**23.18**	





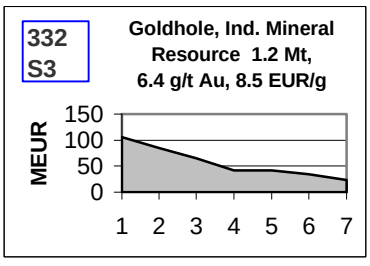


Figure 4. Evaluation of Goldhole Prospect after General Exploration.

GOLDHOLE: Detailed Exploration, Prefeasibility Study, Potentially Economic

The Goldhole deposit mineral resource estimate has been sharpened by detailed drilling: Indicated resource is 2,2 Mt with 5.4 g/t Au. Laboratory tests reveal that part of gold can be enriched by gravimetry and the rest by flotation. Total recovery is 92 %. A separate Cu concentrate can be processed. Production 0.4 Mtpa.

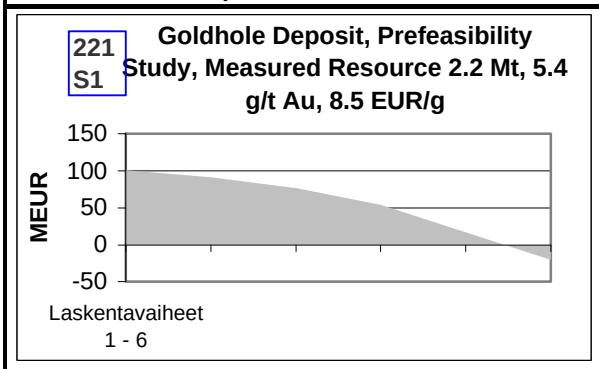
UNCODE 221

Pre-Feasibility Stage	**Scenario 1.**		**Scenario 2.**
Starting situation			
In situ assay I (Au)	5.40	g/t	
In situ assay II (Cu)	0.20	%	
In situ volume	2.20	Mt	
Total gold resource	11.88	t	
Total copper resource	4400.00	t	
Market price for gold	8.50	EUR/g	11
Market price for copper	1.20	EUR/kg	1.4
In situ apparent deposit value	**100.99**	**MEUR**	**130.69**
Effects of production techniques			
Ore loss	10.00	%	
Dilution	20.00	%	
Total feed volume	2.38	Mt	
Feed assay for gold	4.50	g/t	
Feed assay for copper	0.17	%	
Total gold resource in feed	10.69	t	
Total copper resource in feed	3960.00	t	
In situ apparent feed value	**90.89**	**MEUR**	**117.62**
Volume and value of products			
Amount of gravimetric concentrate	29.08	t	
Recovery of gravimetric gold	68.00	%	
Gold assay of gravimetric concentrate	25.00	%	
Amount of gold in gravim. concentrate	7.27	t	
Payable portion of gravim. gold	95.00	%	
Value of gravimetric Au concentrate	**58.71**	**MEUR**	**75.98**
Amount of flotated concentrate	7331.66	t	
Recovery of flotation gold	24.00	%	
Gold assay of flotation concentrate	350.00	g/t	
Amount of gold in flotation concentrate	2.57	t	
Payable portion of flotation gold	75.00	%	
Value of flotation Au concentrate	**16.36**	**MEUR**	**21.17**
Amount of copper concentrate	11880.00	t	
Recovery of copper	60.00	%	
Copper assay of concentrate	20.00	%	
Amount of copper in concentrate	2376.00	t	
Payable portion of copper	65.00	%	
Value of copper concentrate	**1.85**	**MEUR**	**2.16**
Total value of concentrates	**76.92**	**MEUR**	**99.31**

Figure 5A.
Evaluation of Goldhole Prospect after detailed exploration. Value of concentrates.

Investments & operating costs			
Investments			
Exploration	3.00	MEUR	
Mine development	13.00	MEUR	
Pit & stope preparation	3.00	MEUR	
Interests (20 %)	3.80	MEUR	
Investments total	**22.80**	**MEUR**	
Operating costs			
Wallrock stoping	4.00	Mt	
Wallrock stoping cost / t	0.75	EUR/t	
Wallrock stoping costs total	3.00	MEUR	
Open pit mining (feed)	1.80	Mt	
Open pit mining cost / t	2.20	EUR/t	
Open pit mining costs total	3.96	MEUR	
Underground stoping (feed)	0.58	Mt	
Underground stoping cost / t	16.00	MEUR/t	
Underground stoping costs total	9.22	MEUR	
Mine operating costs total	**16.18**	**MEUR**	
Gravimetric processing cost / t	3.50	EUR/t	
Gravimetric processing costs total	8.32	MEUR	
Gold flotation cost / t	4.00	EUR/t	
Gold flotation costs total	9.50	MEUR	
Copper enrichment cost / t	1.50	EUR/t	
Copper enrichment costs total	3.56	MEUR	
Processing costs total	**21.38**	**MEUR**	
Operation overheads, add 25 %	9.39	MEUR	
Transport distance	200.00	km	
Transport cost / t / km	0.07	EUR / t / km	
Transport costs total	0.25	MEUR	
Marginal	15.00	%	
Taxes		MEUR	
Investm. & operating costs total	**97.30**		**97.30**

Goldhole Deposit Summary	Au 50 EUF	Au 70 EUR/g	
1. In situ apparent deposit value	100.99	130.69	MEUR
2. In situ apparent feed value	90.89	117.62	MEUR
3. Real value of concentrates	76.92	99.31	MEUR
4. Remnant value after investments	54.12	76.51	MEUR
5. Remnant value after operating costs	16.56	38.95	MEUR
6. Result after all production costs	**-20.38**	**2.01**	**MEUR**



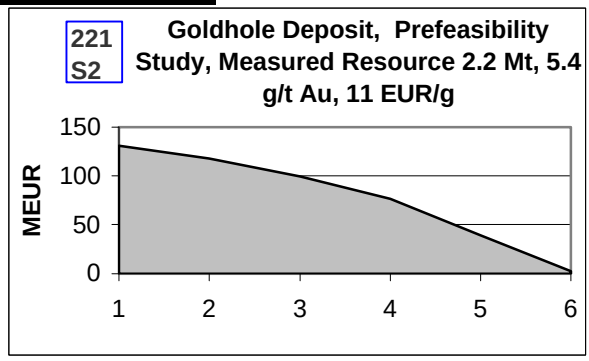


Figure 5B.
Evaluation of Goldhole Prospect after detailed exploration. Prefeasibility study.

3. The Pahtavaara Gold Mine Case

3.1 Description of the Pahtavaara Property

Terra Mining Oy purchased the Pahtavaara Property, located in northern Finland above the Arctic Circle, with an exploration license from the Finnish Ministry of Trade and Industry in 1991. Production commenced in 1996. From 1997 William Resources Inc., Canada have owned it. The Pahtavaara Mine Property includes the Pahtavaara Mine Lease and several prospects outside the mine site; they all are related to well identified geological alteration zones inside the Central Lapland Greenschist Belt and similar to breaks in the Canadian Shield.

From the beginning of production in July 1996 to the end of 1998 1 336 362 tons of gold ore averaging 2.0 g/t Au has been mined. The remaining resources were estimated to be 763 000 tons averaging 2.97 g/t Au. In addition there are several prospects with anticipated resources and in general good gold ore potential within alteration zones of the underexplored Belt.

Mine technical/exploration units in the order of decreasing level of development include:
1. Mined pits
2. Planned pits or reserves
3. Indicated resources
4. Inferred resources
5. Anticipated resources – prospects
6. Inferred and anticipated resources and prospects controlled by other owners.
7. Regional exploration potential.

A simplified diagram of the two critical poles of the Pahtavaara production line, open pit and concentration plant, is shown in Figure 6. Main ore deposit with remaining reserves, resources, and anticipated resources (ore potential) are shown in horizontal and vertical sections, Figure 7. The geological alteration zone hosting gold bearing lodes dips steeply to the north. Different sampling densities for the above ore classes are indicated by drill holes dipping to the south.

A summary report of the Pahtavaara mineral reserves and resources is presented in Figure 8A. A scenario for an ideal state of affairs with reserves/resources is shown in Figure 8B: sufficient reserves for two years and the continual development of resources for 10 to 20 years of production.

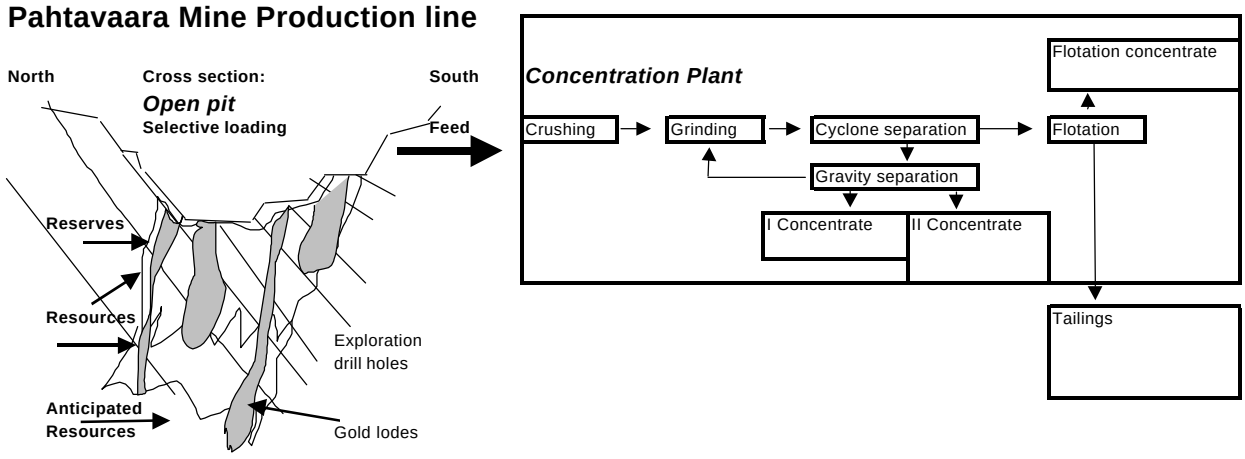


Figure 6.
A simplified diagram of the Pahtavaara Mine production line from open pit to concentration plant.

3.2 Application of the UN Classification

Both UN and local terms and classification criteria are shown in Figure 8A. For a mining company sampling density may be the most important of criteria used for technical or development classification but it seems easy to convert terms to follow the UN recommendation. Sample density is a relative measure depending on the geological and technical characteristics of a deposit and varying from case to case. The classification is static: classes of lower category do not include classes of higher categories.

One category is proposed to be added: "Mined". When classifying active or exhausted mines, the total resources, including those mined, are of interest and give significant information about the deposit type in question.

This classification very clearly points out a crucial weak point in the survival strategy of the mine, the problem of resource development. Annual production being 300 000 to 400 000 metric tons, an ore reserve of 125 000 tons covers only one third of a year. It demands a remarkable effort, time and money, to develop known resources to minable reserves.

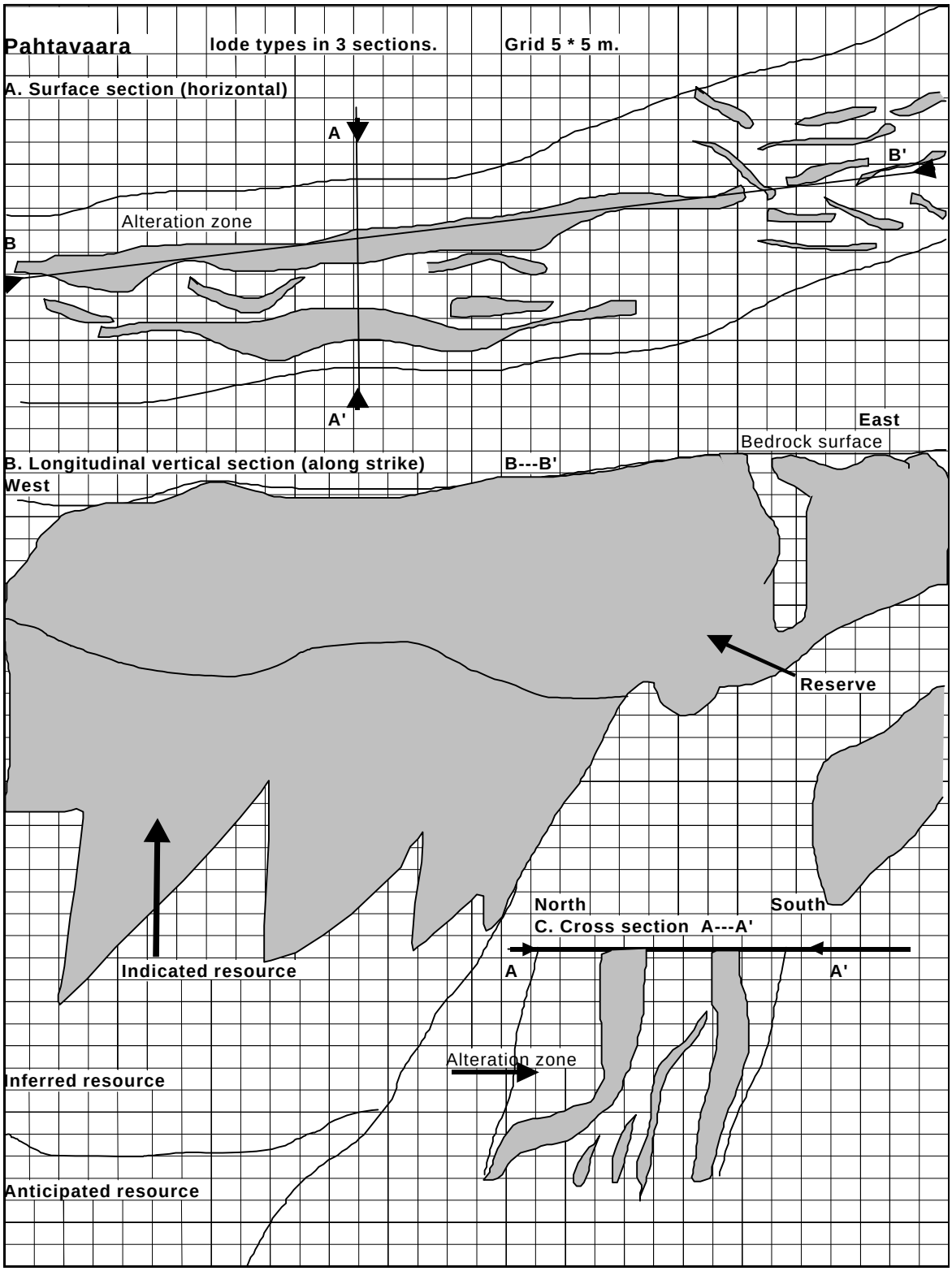


Figure 7. A horizontal section (A), a longitudinal vertical section (B) and a vertical cross section (C) of the Pahtavaara gold ore deposit showing alteration zones hosting gold and criteria for the classification of reserves/resources.

A. The Pahtavaara Mine Case Mine production 0.4 Mtpa

UN International Framework		Detailed Exploration Mt	General Exploration Mt	Prospecting Mt	Reconnaissance Mt
	National System	Sampling grid 15 X 15 m or denser	Sampling grid 30 X 30 m to 15 X 30 m	Drilled Occurrences	Geochemical/structural analogies; outcrops
?	Mined	(000) 1.336			
Feasibility Study or Mining Report	Ore Reserve, Proved	(111) 0.125			
Prefeasibility Study	Ore Reserve, Probable Min. Resource, Measured Min. Resource, Indicated	(221) 0.03	(222) 0.423		
Geological Study	Min. Resource, Inferred Min.Resource, Anticipated			(333) 0.31	(334) 2.0

B. A theoretical "improved case" Mine production 0.4 Mtpa

UN International Framework		Detailed Exploration Mt	General Exploration Mt	Prospecting Mt	Reconnaissance Mt
	National System	Sampling grid 15 X 15 m or denser	Sampling grid 30 X 30 m to 15 X 30 m	Drilled Occurrences	Geochemical/structural analogies; outcrops
?	Mined	(000) 1.336			
Feasibility Study or Mining Report	Ore Reserve, Proved	(111) 0.6			
Prefeasibility Study	Ore Reserve, Probable Min. Resource, Measured Min. Resource, Indicated	(211) 0.4 (221) 0.5	(222) 1.2		
Geological Study	Min. Resource, Inferred Min.Resource, Anticipated			(333) 2.3	(334) 10.0

Figure 8.
A. Pahtavaara Mine Case: the UN and local classifications compared.
B. A theoretical "improved case": reserves/resources necessary to keep continual production running fluently. In these cases the estimates are non-inclusive and additive: total resource is the sum of sub-estimates = (000+111+221+222+333+334) in case A and = (000+111+211+221+222+333+334) in case B.

4. Conclusions

The UN Framework Classification seems to suit very well for reporting exploration and current mining in Finland. Criteria of classification may vary locally but the framework can digest them. In this report the three different ways UN Classification has been applied prove for its flexibility: there are inclusive and non-additive resource estimates, non-inclusive and non-additive estimates, and finally non-inclusive and additive resource estimates described.
